GROWTH AND FLOWERING OF ALSTROEMERIA

BY

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DECLARATION

This thesis is my original work and has not been presented for a degree in any other University.

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This thesis has been submitted for examination with my approval as University Supervisor.

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To my husband Winston Hutchinson

and

Our children, Verrome Jepkemoi

and

Javin Kipruto

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GROWTH AND FLOWERING OF *ALSTROEMERIA*

ABSTRACT

The study was conducted to investigate the growth and flowering patterns of 3 cultivars of *Alstroemeria* and the effect of some floral preservatives on the vase-life of the produced cut flowers.

Propagated rhizomes started sprouting 9 days after planting in all cultivars. 'Pink Perfection' produced more total shoots (flowering and non-flowering) than 'Carmen' and 'Marina'. 'Carmen', 'Pink Perfection' and 'Marina' flowered 132, 215 and 245 days after planting respectively. The number and percentage of flowering shoots were higher in 'Carmen' followed by 'Pink Perfection' and 'Marina' in that order. The average lengths of inflorescences were 94.3 , 82.9 and 47.0 cm in 'Pink Perfection', 'Marina' and 'Carmen', respectively. The percent marketable inflorescences improved with time, reaching their optimums after 31, 40 and 44 weeks from planting in 'Carmen', 'Pink Perfection' and 'Marina', respectively.

Pruning increased the total number of shoots and percentage of new shoots formed in 'Marina'. The average rates of shoot production were 47.42 and 16.75% in pruned and unpruned hills, respectively. The total number of cut flowers from pruned hills were 50.83% more than from the controls. The average length of cut stems were 119.6 and 96.2cm from pruned and unpruned hills, respectively. The average diameters of cut stems were 1.07 and 0.90 cm from pruned hills and controls, respectively. Pruning had no influence on the percent marketable stems. More white grade (≥ 70 cm long) cut stems and less blue (60 - 69 cm long) and yellow (50-59 cm) long grades were however produced from pruned hills than the controls.

Sucrose, at 4% did not improve the vase life of the cut flowers of Alstroemeria cvs 'Carmen', 'Marina' and 'Pink Perfection'. All petals were shed at the same time as the controls. Petals from all cut flowers pretreated for 1 hour in silver thiosulphate complex, then held in deionized water were shed 8, 7 and 6 days later than the controls in 'Carmen', 'Pink Perfection' and 'Marina', respectively. However, those cut flowers held in 4% sucrose solution instead of

deionized water shed all petals 6, 4 and 2 days later than the controls in 'Carmen', 'Pink Perfection' and 'Marina', respectively. Petals from all cut flowers pretreated for 1 hour in 2.5% chrysal, then held in deionized water were shed 9. 6 and 6 days later than the controls in 'Carmen', 'Pink Perfection' and 'Marina', respectively. However, those held in 4% sucrose solution instead of deionized water, shed all petals 5, 4 and 2 days later than the controls in 'Carmen' 'Pink Perfection' and 'Marina', respectively.

INTRODUCTION

Cut flower production in Kenya is becoming increasingly popular to small scale farmers as a source of income from domestic and export markets. Cut flowers form a major export commodity within the horticultural produce constituting about 18% by volume and 41% by earnings (Waithaka, 1985). Cut flowers grown in Kenya include Alstroemeria, carnations, roses, orchids, Statice, tuberose, Ornithogalum, Liatris and Heliconia. Florist greens include asparagus, fern, eucalyptus, leather leaf, Dracaena, Cordyline and Dieffenbachia.

Alstroemeria has become an important cut flower in Kenya. It is thought to have been introduced to Kenya in the late 1960's or early 1970's by former British settlers. The three predominant varieties grown in Kenya are 'Carmen', 'Marina' and 'Pink Perfection'. Alstroemeria is grown as a perennial cut flower. It is mainly grown in Limuru and Naivasha areas.

Alstroemeria belongs to the family Amaryllidaceae and is believed to be native of South America (Baker, 1888; Robinson, 1963; Uphof, 1952). It is mainly

propagated by division of the fleshy underground sympodial rhizomes from which arise aerial shoots. The rhizome apex developes from an auxillary bud on the first scale leaf of the previous aerial shoot (Buxbaum, 1951). Thus, each succeeding aerial shoot from the rhizome is indeed an auxillary shoot from the previous aerial shoot. The auxillary bud on the second scale leaf on the shoot has also the potential to become a rhizome. All other nodes up the aerial stem lack auxillary buds. Roots can be thin and fibrous, thick and fleshy or both types. The adult leaf twists at the junction of the sheath and the blade causing the leaf to be inverted 180^{o}. The stomatae on the adaxial side of the leaf seem likewise inverted. The inflorescence is a whorl of cymes at the top of the stem (Wilkins and Heins, 1976).

This study was initiated to investigate the following: The outdoor growth and flowering patterns of Alstroemeria with special emphasis on shoot and flower production, quantity and quality of cut flowers produced; the effects of shoot pruning on shoot growth, flower production and quality of inflorescences; and the effect of some floral preservatives on the vase life of the cut flowers produced.

LITERATURE REVIEW

A. Growth and flowering

The growth performance of a crop is determined by its genetic makeup and the environmental factors where it grows. This performance could be in terms of total yield, measured by total dry matter accumulated or the economic yield, measured by flower and or fruit yield. Growth and development of crop plants consist of 2 distinct, though overlapping phases, the vegetative and reproductive phases. The vegetative phase deals with development of the stems, leaves and absorbing roots, while the reproductive phase deals with formation and development of flower buds, flowers, fruits and seeds or the enlargement and maturation of storage organs (Wareing and Phillips, 1981). Various indices of flowering have been used to describe the flowering response process. Some of these are, the total number of flowers or total number of flowering nodes, the percentage of flowering plants in the total group receiving a particular treatment, the time to the first appearance of flowers (the shorter the time, the greater the response), the number of leaves formed before flower initiation, and the use of a scale of

scores depending on the stage of development reached by the flowers (Wareing and Phillips, 1981).

Some environmental factors that affect growth performance include temperature, light, water, nutrient levels and soil properties. Temperature and light are among the most prominent factors affecting growth and flowering of Alstroemeria (Healy et al., 1982; Heins and Wilkins, 1979; Lin and Molnar, 1983).

Vegetative shoot formation in Alstroemeria was shown to be stimulated by high daily temperatures of 25°C and 21°C and depressed by low temperatures of 9-17°C and 15°C in 'Orchid' ('Walter fleming') and 'Regina' cultivars, respectively (Healy and Wilkins, 1979; Heins and Wilkins, 1979; Vonk Noordegraaf, 1975). Vonk Noordegraaf (1975) working with 'Regina' demonstrated that 9°C growing temperatures promoted production of a greater ratio of flowering shoots over vegetative blind ones, compared to 25°C.

Flowering of Alstroemeria was induced by low temperatures of 9-13°C and 15-18°C and inhibited by high temperatures of >25°C and 21°C in 'Orchid' and 'Regina' cultivars, respectively (Healy and Wilkins, 1979; 1982; Heins and Wilkins, 1979; Vonk Noordegraaf, 1975). The 'Orchid' and 'Regina'

cultivars had 2 main flowering periods, annually in the Netherlands: Spring (May) when average daily temperatures were about 10-14.5°C and fall (August, September, October) when average daily temperatures are about 10-18°C (Molnar, 1975). Flower production in the United States of America and Canada is restricted to spring and early summer when temperatures are moderately high (Heins and Wilkins, 1976). 'Orchid' cultivar was, however, reported to flower in the autumn (Fall) (Molnar, 1975). 'Regina' cultivar exhibited long non-flowering periods during the winter when temperatures were very low showing that some form of vernalization was required for flower induction (Healy and Wilkins, 1979; 1982; Heins and Wilkins, 1979; Molnar, 1975). The cold treatment for 'Regina' was fulfilled either at 5°C for a period of 6-8 weeks or at 13°C for a period of 16 weeks (Healy and Wilkins, 1979; 1982). The total shoot (Vegetative and reproductive) production during the flowering time decreased as the duration of the 5°C treatment increased for undivided one-year old plants. The total shoot production during the flowering period for one year old plants divided into single rhizomes, however, increased as the duration of the 5°C treatment increased (Healy and Wilkins,

1979).

Similar responses of growth and flowering to temperature have been reported in other cut flowers. Flowering in Lilium longiflorum Thunb similarly occurred at any temperature below 20°C but more rapidly, if bulbs were given 6 weeks of low temperature treatment at 5°C (DeHertogh et al., 1969; Wilkins, et. al., 1980. Low temperature treatment was required for rapid, uniform shoot emergence, rapid growth and early flowering (DeHertogh and Wilkins, 1971; Stuart, 1967; Wang and Roberts 1970). Temperature requirements in orchids varied with cultivars (Sheehan, 1980). Cymbidium orchids required 10°C night temperatures for flower induction. A 10°C and 21-24°C night and day temperatures., respectively, were found to be ideal for cymbidium flowering (Sheehan, 1980). Cattleya orchids thrived best with night temperatures between 15°C and 18°C. Phalaenopsis orchids, especially the white flowered cultivars, grew best at 18°C night temperature and upto 27°C day temperatures. Pink Phalaenopsis cultivars flowered better at 13-15°C night temperatures (Sheehan, 1980). Miller (1958; 1959; 1962), and Tayama and Miller (1965) showed that optimum growing

temperatures for snapdragons, based on dry weight accumulation of the tops of the plant, decreased from a high of 27°C for young seedlings held at constant day and night temperatures, to a low of about 15°C for plants approaching flowering. A series of plants grown at various night temperatures showed optimum temperatures varying from 20°C for young plants to 13°C for plants near flowering (Rogers, 1980). These differences were shown to be due to changes in the ratio of leaf to total plant dry weights as plants aged. Higher flowering of Nerine flexuosa Alba occurred after growth at low temperatures of 9.0 and 13.0°C (Fortainer et al. 1979). Temperatures of 17.0 and 21.0°C were too high for flowering. A combination of 9.0°C during growth and 21.0°C during storage resulted in 100% satisfactory flowering and acceptable bulb growth of Nerine flexuosa Alba (Fortainer et al., 1979).

Other cut flowers unlike Alstroemeria 'Regina' and Lilium longiflorum Thunb showed a well defined low temperature requirement for flower bud initiation and development. Liatris spicata L corms required a cold treatment of 8 weeks at 3-5°C for early,uniform flowering, increased length of

inflorescences and percent marketable inflorescences (Waithaka and Wanjao, 1982). The majority of mature dormant Liatris corms left in the soil during the wet and cool months of May, June and July in Kenya sprouted during the preceeding months, however, the percentage of flowering was very low and late (Waithaka, 1985). The produced inflorescences were also short and unmarketable. This meant that the low soil temperatures were just enough for releasing the corms from dormancy but not low enough for elongation of floral stalks (Waithaka, 1985).

From results obtained from experiments with henbane, petunia, beet, cabbage and Lunaria, Melchers and Lang (1948) suggested that a transmissible flowering stimulus which they called Vernalin was formed as a result of cold treatment. It was further suggested that Vernalin and florigen, the flowering hormone are independent, and that Vernalin must be present for florigen to be formed (Wareing and Phillips, 1981).

Besides temperature, daylength has been noted to influence growth and flowering of many cut flowers. Vegetative shoot formation in Alstroemeria 'orchid' was stimulated by short days (8 hr day length) and inhibited by long days (>12 hrs) (Heins and Wilkins

1979). Long days (>12 hrs) had little effect on vegetative growth but short days (8 hrs) inhibited shoot formation in 'Regina' cultivar. Flowering of 'orchid' was induced by long days (>12 hrs), although initiation occurred in short days (8 hrs). High temperatures (25°C) inhibited flowering irrespective of photoperiod (Healy and Wilkins, 1979; 1982; Heins and Wilkins, 1979; Molnar, 1975). In 'Regina', flowering was induced by long days (>12 hrs) and inhibited by short days (8 hrs) (Heins and Wilkins, 1979; Lin and Molnar, 1983). The 'orchid' cultivar of Alstroemeria continued to flower throughout summer (long days) and winter (short days) as long as sufficient solar radiation was available to prevent flower bud abortion (M.C. van Staaveren, Personal communication). 'Regina' would not flower in the fall and early winter (short days) even if favourable temperatures were provided, after it had stopped during the long days and high temperatures of summer (Molnar, 1975). Healy and Wilkins (1979), further observed that in 'Regina', flowering occurred only in long days after the plants had been exposed to temperatures of 13-15°C for an extended period of 90-120 days. 'Regina' produced 20% more stems per plant and were taller when grown under long photo-

periods (16 hrs) than under short days (<12 hrs) (Molnar, 1975). Plants exposed to long days (16 hrs) flowered 6 weeks earlier and had 30% greater percentage of flowering shoots compared to those under short days (8 hrs) (Healy and Wilkins, 1979; Molnar, 1975). 'Regina' outyielded 'orchid' cultivar by more than 40% on a plant to plant basis (Molnar, 1975). Flower initiation in Carnation (Dianthus caryophyllus L) was delayed by short days (<12 hrs) (Kusey Jr. et al., 1981). Six weeks of continuous light, started at the 7th visible leaf pair, the stage at which reproductive vegetativeness ends in carnations, promoted flowering (Kusey Jr. et al, 1981). Long days (>12 hrs) promoted the flowering of Gypsophila paniculata L cultivar 'Bristol fairy' (Shillo and Halevy, 1982; Kusey Jr. et al., 1981). Critical photoperiod of several selections of 'Bristol fairly' ranged from 12-18 hrs. These long photoperiods were effective only at relatively high temperatures. Plants remained vegetative even in long days when night temperatures were below 12^{o}C (Shillo and Halevy, 1982). Daylength exerted quantitative effects on snapdragons. Plants have therefore been classified as quantitative long day plants (Hedley, 1974). Long days hastened flowering in most cultivars of

snapdragons while short days retarted, but did not completely prevent it. Snapdragons reacted most markedly to day length treatments when they had 10 to 12 leaves (Maginnes and Langhans, 1967), or 5 to 7 weeks after seeding (Rogers, 1958; Maginnes and Langhans, 1967). Long day treatments applied prior to the beginning of and during this light-sensitive stage of snapdragons reduced the number of leaves produced by the plant, hastened flower bud initiation, shortened stems and also hastened flower development to marketable stage (Rogers 1958; Maginnes and Langhans, 1967). Short-day treatments applied at the same stage of development caused opposite effects. Although temperature modified photoperiod responses of some cultivars of snapdragons it was shown to have a minor influence on flowering except it affected overall growth rates (Maginnes and Langhans, 1967). Long days delayed flowering but increased percent flowering and enhanced flower quality in gladiolus cut flowers (Jones, 1929; Kosugi, 1962; Weinard and Decker, 1930; Yasuda and Hashimot, 1952; Yasuda and Yokoyama, 1954). A 9-hour photoperiod caused flower blasting of many gladioli cultivars whereas 10-11 hours induced satisfactory flowering and reduction of blindness (Yasuda and Hashimoto, 1952;

Yasuda and Yokoyama, 1954; Mckay, 1979; Shillo *et al.*, 1980). The effect of daylength in roses was temperature dependent. Long days promoted flower initiation (Mor, 1972). At low temperatures, rose shoots differentiated more leaves before flower initiation with short days (8 hrs) than long days (16 hours). At high temperatures, there was no significant differences (Mor, 1972).

Interactions between cold temperature treatment and photoperiod have been studied in a number of plant species. There were no indications that photoperiodic treatments could substitute for cold treatment in *Alstroemeria* to induce flowering as was shown in *Dicentra* (Lopes and Weiler, 1977) and *Lilium longiflorum* Thunb (DeHertogh *et al.*, 1969; Weiler and Langhans, 1976). Heins and Wilkins (1982) suggested that there existed a phasic flowering mechanism in *Alstroemeria* where the thermophase must precede photophase before flowering takes place. Plants would, therefore, develop vegetatively during the cool rainy season, then flower during periods of warmer temperatures and longer photoperiods until too high temperatures inhibit flowering (Healy and Wilkins, 1982; Heins and Wilkins, 1982). Nutrition was indicated as a possible factor controlling

flowering in Alstroemeria (Healy and Wilkins, 1982). They reported that when Alstroemeria was grown at temperatures less than 15°C, there was an increased storage root growth and enlargement. A marked increase in rhizome to shoot growth ratio was observed when Agropyron and Poa pratensis were grown at 13 and 15°C compared to 25°C and 18 or 24°C, respectively (McIntyre, 1970; Mckell et al., 1969). Heins and Wilkins (1979) proposed that the starch in storage organs (roots) of Alstroemeria was a possible source of carbon required for rapid development of inflorescences. When Dactylis was grown at 10°C or 20°C under 8 or 16 hours photoperiods, plants exposed to 16 hours showed greater accumulation of dry matter in shoots compared to roots than those grown at 8 hour photoperiod (Eagles, 1971). Long photoperiods may have enhanced plant growth substances relationships within Alstroemeria that could be promoting flowering (Healy and Wilkins, 1982). Gibberellic acid (1000 mg/ℓ) treated plants had elongated shoots with leaves longer than they were wide, which morphologically resembled a flowering shoot (Healy and Wilkins, 1982). This suggested that gibberellic acid may have been involved with elongation of flowering shoot but not flower initiation.

B. Shoot pruning

Pruning is a major horticultural practice in the production of many ornamental plants, tree fruits, small fruits and nuts (Edmond et al., 1977). The primary aim is to improve yield, size, colour, shape and or quality of flowers or fruits. Other aims include shaping the crop for beauty and or ease of crop management. The pruning of shoots influences the vegetative/reproductive balance in plants (Edmond et al., 1977).

Shoot pruning has been an important cultural practice used in the growing of roses (Zielslin and Mor, 1981). Direct pruning and gradual cut back are the 2 methods employed in rose pruning Rose pruning was done mainly to control plant growth, to facilitate cultural practices such as spraying for pests and to promote sprouting of lateral shoots which became strong sinks of metabolites (Kohl et al., 1967; Mor and Halevy, 1979). Severity and time of pruning of roses influenced subsequent flower production and renewal of shoots. Roses were pinched continuously during the entire period of growth to improve quality of stems and at scheduled times to produce inflorescences for specialized markets by

shifting production from one period to another (Laurie et al., 1980). This was done in various ways to improve flower production, branched plants, larger diameter canes and longer stemmed flowers.

Greenhouse grown Stephanotis floribunda L. that had excess or dense vine growth were less apt to flower because of shading of lower leaves (Kofranek and Kubota, 1981). Severe pruning in spring developed new vine growth that was receptive to extended photoperiod for flower induction (Kofranek and Kubota, 1981). Abundant lateral shoots and flowers were obtained by pruning begonias (Larson, 1980). This has to be controlled because crowding resulted in poorly formed, excessively succulent and tall plants with higher disease incidence (Larson, 1980).

Strong Alstroemeria plants are desirable as this would favourably influence flower quality (Healy and Wilkins, 1979). Shoot thinning of 'Regina' and 'Orchid' cultivars increased flower production (Heins and Wilkins, 1976; Molnar, 1975; Vonk Noordegraaf, 1975).

C. Effect of Floral Preservatives on Vase-life of Cut flowers.

The short vase-life of various cut flowers is

a pressing problem of the florist industry (Sacalis, 1973). The length of vase-life varies with plants. Roses might last for 5 days (Laurie et al., 1980; Sacalis, 1973); Carnations, 3-7 days (Laurie et al., 1980; Le Masson and Nowark, 1981; Sytsema, 1980); Gypsophila 5-7 days (Laurie et al., 1980); Gerbera jamesonii, 3-8 days; Ranunculus asiaticus L, 3-5 days and Strelitzia reginae L., 7-10 days (Laurie et al., 1980 . Some have longer vase-life e.g. chrysanthemums, 14 days, Cymbidium orchids, 28 days (Laurie et al., 1980) and some Parigo hybrids of Alstroemeria, 21 days (Molnar, 1975).

Early flower senescence is partially caused by water stress in leaves and flowers (Durkin and Kuc, 1966; Halevy and Mayak, 1981; Kofranek and Paull, 1973; Paull and Goo, 1985). The water balance of the flower is ~~a result of water balance in the flower~~ as a result of water uptake and transpiration losses (Laurie et al., 1980). After cutting the floral stems, the transpiration rate remains nearly constant while the absorption rate declines continuously. The absorption rate is determined by the water potential gradient along the cut stem and by the resistance to water flow from the vase to the petals. A reduction in water uptake is partially caused by a build-up of

bacterial growth in the vascular tissue of the floral stalk (Duckin and Kuc , 1966; Halevy and Mayak, 1981; Kofranek and Paull, 1973; Paull and Goo, 1985) and partially by physiological blockage caused by wound gums. The physiological blockage has been termed 'bent neck' in roses (Burdett, 1970; Kohl, 1961; Sacalis, 1973). Similar blockage was reported in Anthurium (Paull and Goo, 1982; Laurie et al., 1980; Walker, 1969). Although 'bent-neck' in roses may have been caused by microbial blockage (Aarts, 1957; Burdett, 1970), a continued reduction in water uptake was observed from sterile holding solutions (Marousky,1969 ; 1971). This continued reduction in conductive ability of water by cut stems, first noted by Kuc (1964) and later studied in excised stem segments of rose and Anthurium plants by others (Burdett, 1970; Duckin and Kuc, 1966; Gilman and Steponkus, 1972; Marousky, 1969), has been termed physiological blockage. Paull and Goo (1985) and Walker (1969), suggested that this vascular occlusion was due to ethylene-stimulated production of gums. Buys and Cours (1980), reported that the formation of oxidation products by reactivation of polyphenoloxidase or peroxidase enzymes are responsible for the blockage in floral stem.

The role of ethylene in accelerating senescence of cut flowers is widely accepted (Burg, 1973; Kader, 1985; Rogers, 1973). The known physiological and biochemical effects of ethylene on cut flowers include increased respiratory activity, increased cell permeability, loss of cell compartmentalization and alteration of auxin transport and metabolism (Pratt and Goeschl, 1969). Some of the morphological effects include in-rolling of petals; fading, wilting and abscission of flowers; and chlorosis, epinasty and abscission of leaves (Kader, 1985). These ethylene effects accelerated and consequently shortened the post-harvest life of cut flowers. Attack by post-harvest diseases and pests reduce marketability of cut flowers.

Normal maturation and physiological aging of cells also limits the vase-life of cut flowers (Dickey, 1951 Fischer 1953).

(i) Use of Sucrose as a Post-harvest Preservative of Cut Flowers.

Flower petals accumulate high levels of carbohydrates during their development on the parent plant (Nichols, 1973). When the flower is cut, the rate at which sugar is metabolised is one of the

factors that determines its vase-life (Nichols, 1973). The main effect of the sugar is considered to be a respiratory substrate and a basic metabolite for the growing flower (Coorts, 1973; Rogers, 1973). Studies have, however, shown that substrate limitations are not entirely responsible for the short vase-life of cut flowers (Kaltaler and Steponkus, 1976; Nichols, 1973). Sugars at optimum concentration, taken up by these cut flowers accumulated in petals. These sugar concentrations were probably higher than required for metabolic purposes (Sacalis, 1973).

Sugars prevented wilting of flowers held in water. Combes (1938) and Sourie (1938) suggested that the relatively high concentrations of soluble sugars in cut flowers contributed a large part to the osmotic potential of the floral tissues, thereby, improving their water content. It was also suggested that the effect of osmotic potential was brought about by maintaining mitochondrial (Kaltaler and Steponkus, 1976) and membrane integrity (Coorts,1973;Sacalis, 1973) or by enhancing cuticle synthesis in the petals (Sacalis, 1973). Sugars also reduced water loss through closure of stomatae (Marousky, 1973).

Other workers have shown that sucrose interacted with the effect of several growth regulators on the

senescence of cut flowers by enhancing the effect of cytokinins, reducing the damaging effects of ethylene (Mayak and Dilley, 1976) and antagonising the effects of abscissic acid (Borochov et al., 1976).

Soluble sugars, such as sucrose are generally accepted to form the largest proportion of the sugar pool in the mature flower (Marousky, 1971; Nichols, 1973; Sourie, 1938; Weinstein, 1957). This supported the view that floral tissues are active metabolic centres. The sugar content of the cut flower was therefore maintained by feeding soluble sugars through cut ends of the floral stems (Nichols, 1973). The extent to which the longevity of cut stems was maintained varied with plant species. Cut roses that lasted 5 days in water lasted 8 days in a sucrose solution (Sacalis, 1973). Carnations that lasted 6 days in water often lasted as long as 14 days in a sucrose solution (Sacalis, 1973). The same treatment applied to Narcissus, however, caused only a small improvement in longevity, but resulted in substantial growth of the ovary (Nichols, 1973). The vase-life of Carnation CV. Samantha at bud stage was upto 10 days in a 6-8% sucrose vase solution and only 5 days in water (Amariutei and Burzo, 1981). The sucrose was absorbed through the cut ends of stems,

thus extending longevity of carnation flowers (Aarts, 1957; Larsen and Frolich, 1969; Nichols, 1968; 1973). Treatment of cut flowers with high concentrations of sucrose (5-40%) prior to shipment greatly improved the quality and extended vase-life of gladiolus (Bravdo et al., 1974; Halevy and Mayak, 1974; Mayak, et al., 1973), Carnations (Halevy and Mayak, 1974) and Chrysanthemums (Kofranek and Halevy, 1972). Increasing sucrose level in holding solutions upto 16% markedly delayed the onset of autocatalytic ethylene production (Dilley and Carpenter, 1973). Immersing gladiolus cut stems in a solution of high sugar concentration (20%) for 20 hours at 20°C improved the opening and size of florets and increased longevity of lower spike (Mayak et al., 1973).

The principle sugars of carnation corolla (White sim) are reducing sugars and sucrose; the former predominating at all stages of flower development (Nichols,1973). During senescence, the total sugar content declined until about half of the initial weight of reducing sugar remained at incipient wilting whereas sucrose practically disappeared

(Nichols, 1973). In Narcissus CV. 'Actaea', the ratio of the concentrations of sugars depended on the stage at which the flower was cut (Nichols, 1973). At the proper cut stage of flower development of daffodils, reducing sugars increased to a maximum, roughly coincident with full flower opening and then decreased until half of the maximum remained at wilting. Sucrose, the predominant sugar in the corolla of the Narcissus bud, disappeared as reducing sugars increased (Nichols, 1973). The residual pool of reducing sugars at incipient wilting suggested that wilting was not caused by depletion of respiratory substrate. The evidence suggested that in Narcissus, there was continuous movement of sugars and water to the ovary. It postulated that treatment with sugar had a greater effect on the water relations of the ovary than on the corolla since the ovary continued to grow after the corolla had abscissed (Nichols, 1973). Sucrose, however, favoured translocation of sugars and water in carnation to the petals, thus delaying their senescence (Nichols, 1973).

(ii) Use of Silver Ion as a Post-harvest Preservative of Cut-flowers.

Silver thiosulphate complex was reported to have

a very good effect on the vase-life of many carnation cultivars, the effect being somewhat greater on standard than spray cultivars (Veen and Geijn, 1978; Nichols, 1975). Extremely short pulses of silver thiosulphate were sufficient to double the vase-life of carnations (Reid et al., 1980) but osmotic potential was little affected (Veen, 1979). More flowers of Lilium 'Enchantment' reached full bloom and Vase-life was longer after silver thiosulphate complex was used as a preservative (Farnharm, et al., 1980). Effects of a silver thiosulphate complex pretreatment on Gladioulus cut stems increased the percentage of opened florets.

Many ornamental crops can be protected from the detrimental senescence effects of ethylene by treating them with silver ion in the form of silver nitrate or the anionic complex of silver thiosulphate (Kader, 1985). The silver ion from silver thiosulphate complex apparently reaches the ethylene receptor sites through the xylem while that from silver nitrate reaches through external plant surface. This suggested that the active sites were probably in cells and/or on the surface of adjacent plasma membrane (Todaka et al., 1978; Liebermann, 1979; Veen et al., 1980). Irrespective of the site, the major response was an apparent maintenance of stem water uptake (Paull and Goo, 1985).

Similar patterns have been reported in roses and carnations (Comprubi and Fontarnau, 1977; Duckin and Kuc, 1966; Mayak et al., 1973). Tulips and Narcissus did not, however, show any response to silver ions in terms of the rate of water uptake (Halevy and Mayak, 1981; Nichols and Kofranek, 1980; Swart and Kamerbeek, 1979). Differences in responses to silver was, therefore, a reflection of different physiological activity of receptor cells (Nichols, 1980).

Silver ion from silver nitrate extended the vase life of carnation cut flowers from 6 to 8 days (Kofranek and Paull, 1973). Immersion of cut stems for an optimum period of 10 minutes in 1000 or 1200 ppm of silver nitrate extended vase-life of carnations and chrysanthemums (Kofranek and Paull, 1973). Pulse treatments of cut stems with silver nitrate inhibited ethylene-induced vascular occlusion (Paull and Goo, 1985). Silver thiosulphate anionic complex applied to floral stem bases was transported quickly to the flower, thus proving more mobile than silver nitrate (Veen and Geijn, 1978). It also proved to be better than silver nitrate alone in improving vase-life of cut flowers (LeMasson and Nowark, 1981; Sytsema, 1980).

Chrysal chemical has been described as a solution to precondition roses by Buys and Cours (1980) and Salinger (1973). Chrysal, 1.25%, delayed 50% and complete senescence of carnations, when compared with 8-Hydroxy-quinoline citrate + sucrose, dichlorphen and sucrose and tap water (Salinger, 1973). Gerbera flowers in 1.2% chrysal lasted longer than those in water (Bakker and Elst, 1958).

The silver ion (Ag^+) could be acting as a biocide during the postharvest life of cut flowers (Aarts, 1957; Kofranek and Paull, 1973) interfering with wound ethylene binding sites (Sisler, 1982) or with ethylene metabolism (Beyer, 1979). Silver ions react with ethylene to form a complex (Yang, 1985) but such a simple effect of silver ions has been ruled out as a sole possible mechanism of action in prolonging the vase-life of cut flowers. The exact mechanism by which they block or reduce ethylene action has remained unknown. The effectiveness of the silver ion (Ag^+) in reducing ethylene action declined with increasing ethylene concentration (Yang, 1985). It was assumed that one or more of the coordinating Ligands (L) in the reception site facilitated the binding of ethylene to the receptor. This resulted to the formation of

a biologically active complex that could be utilized by the plant cells during metabolism. The silver ions when applied interacted with these coordinating ligands, resulting in the receptor having little capacity to bind ethylene (Yang, 1985).

MATERIALS AND METHODS

Site

The study was carried out at the Agricultural Development Corporation (A.D.C.) Updown farm, Limuru and at the University of Nairobi, College of Agriculture and Veterinary Sciences at Kabete.

Rainfall in Limuru is bimodally distributed. The long rains fall from March to June while the short rains fall from October to December. The annual rainfall is between 900-1000 mm. The mean maximum day temperature is about 20.0°C and the mean minimum is 10.1°C. The period from June to October is cool, cloudy and dry while that from the middle of December to the middle of March is the warmest season. Appendix AI presents the climatic data for the period of the experiment. The soil is dark reddish brown to dark-red in colour; has friable clay, a favourable water retaining capacity and is well drained (Garibaldi, 1977).

Plant Material

Alstroemeria was propagated by division of fleshy rhizomes. Three cultivars 'Carmen', 'Marina'

and 'Pink Perfection' were used for the study. Rhizome divisions used for planting had 5 aerial stems/or visible buds and a non-bruised terminal bud. These propagules were dipped in Lesane solution (.5g/ℓ phenaminosulphate) for 15 minutes before planting 2 rhizomes/hole. The planting was done on double rows on 1 metre wide raised beds, with a spacing of 60 cm between rows and 1 metre between beds. The propagules, planted in a zigzag manner were spaced 90 cm apart. The guard rows were however single rows of plants planted on 50 cm wide raised beds. The adopted spacing by growers in Kenya from the Netherlands is 60 cm between plants and 50 cm between beds. The wider spacing was adopted in this study for ease of data collection. The rhizomes were planted at a depth of 8-10 cm. The crop was supported at two heights with wire lines crosslined with bamboo sticks. The first support was done at 40 cm, then the second one at 80 cm. This promoted the production of straight inflorescences. The fields were hand weeded as frequently as was judged necessary to maintain them weed-free. Hills of approximately the same size were randomly chosen from a 1 year old 'Marina' field for the pruning experiment.

Cut stems for the post-harvest experiment

were harvested at bud stage, 3 weeks after the last nitrogen fertilizer application. Marketable inflorescence above 65 cm long were transported to reach Kabete within 2 hours after harvesting. Stems of approximately the same width were recut to 60 cm long. The lower 25 cm of cut stems were defoliated. This left 18 leaves for 'Marina', 20 for 'Pink Perfection' and 10 for 'Carmen'. Defoliation has been practiced by florists to avoid emersion of leaves into vase solutions.

Plant Culture

Magmax liming material (Calcium oxide + Magnesium Oxide) was broadcasted at the rate of 0.225 kg/m^2 to raise the soil pH from 5.3 to around 6.0. Diammonium phosphate fertilizer at 10 gm/planting hole was mixed with the soil before planting. Nitrogen fertilizer in the form of Calcium ammonium nitrate (26% N) was topdressed at the rate of 15 gms/hill ones a month but every fortnight when the rains were heavy.

Experimental Design

The experiment on growth and flowering patterns of Alstroemeria were laid out on a completely randomised block design and replicated 3 times in blocks. Three

varieties 'Carmen', 'Marina' and 'Pink Perfection' were used. Experimental plots measured 1.00 by 4.50 metres. 8 hills were planted in each plot and 4 hills were used to collect the data. The 4 outer hills served as guard plants.

One year-old hills having between 150-160 total shoots (flowering and non-flowering) were chosen for the pruning study. Pruning was done by pulling out 100 blind shoots per hill. The practice was done once when the plants were vigorously growing following the onset of the rains. This experiment was laid out on a completely randomized design and replicated 5 times. Treatments were randomized over the chosen hills.

A factorial experiment was designed for the experiment on the effect of floral preservatives on the vase-life of Alstroemeria cut stems. Floral preservatives were the factors examined. The 6 treatments with preservatives were; the control (Deionized water), 4% sucrose, silver thiosulphate complex, 2.5% chrysal, silver thiosulphate complex + 4% sucrose, and 2.5% chrysal + 4% sucrose. The 3 varieties of Alstroemeria used were 'Carmen','Marina' and 'Pink Perfection'. Twenty stems per treatment were used for the study, 12 being recorded. The treatment combinations were replicated 3 times. The

average temperature and relative humidity in the experimental laboratory were 20-23°C and 65%, respectively.

Vase Solutions

Deionized water was used to make vase solutions. As this may have been contaminated with bacteria or unchanged colloidal material, 4 ppm sodium hypochlorite was added as a biocide in all vase solutions (Reid and Kofranek, 198

Four percent sucrose was used in the study. Fourty grammes of commercial sucrose was dissolved in 1 litre of deionized water. Cut stems were held continuously in the sucrose solution.

Silver thiosulphate complex was made by first dissolving silver nitrate and sodium thiosulphate separately in deionized water, then mixing the two solutions to make the complex. Silver nitrate (0.068 gms) dissolved in 500 mls of deionized water was added to a solution of 0.79 gms sodium thiosulphate dissolved in 500 mls of deionized water. This gave a 0.2 mM and 1.6 mM concentrations of silver nitrate and sodium thiosulphate, respectively. The preparation of solutions was done in flasks covered with black polythene to maintain stability of the anionic silver

thiosulphate complex. The silver thiosulphate is only stable in excess sodium thiosulphate (Sytsema, 1980; Gorin et al., 1985).

Chrysal, manufactured by Bendieu-Naarden of the Netherlands was also used in this study. Chrysal is a chemical carrier of silver ions in the anionic silver thiosulphate complex form. It also contains gibberellic acid and a fungicide (benlate). Twenty five grammes of chrysal were dissolved in 1 litre deionized water to give a 2.5% concentration.

Treatments

Alstroemeria cut stems were first held for 1 hour in chrysal or silver thiosulphate complex; then half of these were transfered to a vase solution of deionized water. The other half were held in 4% sucrose solution for the remaining period of the experiment.

Parameters of Observation

Data from the experiment on growth and flowering patterns of Alstroemeria were taken on time and rate of shoot emergence from the soil and flowering; number of total shoots (flowering and

Vegetative shoots) and flowering shoots, the length of inflorescences; percentage of flowering and marketable inflorescences for the three cultivars 'Marina', 'Carmen' and 'Pink Perfection'. The number of sprouted rhizomes were recorded every 3 days and was used to calculate the percent emergence with time. For the experiment on the effect of shoot pruning on shoot and flower production, data on the number of total and flowering shoots, length of floral stems and percent marketable cut flowers were recorded.

Data on flowering in the experiments on growth and flowering and on pruning were taken when at least one flower bud on the cyme started to open. Cut flowers were graded according to their lengths and leaf arrangements along the stem. Based on stem length, 3 marketable grades were recognized: (1) white grade measured 70 cm and above; (2) blue grade, 60-69 cm long (3) yellow, 50-59 cm long. Some floral stems had very closely spaced leaves just below the cyme compared to the rest of the cut floral stems. This gave rise to uneven leaf arrangement along the stem. These cut stems together with those shorter than 50 cm were regarded as market rejects. All data were taken on a weekly basis. Data on the post-harvest

experiment were taken every 3 days. The vase-life of the cut flowers measured by the time taken to sheding of all petals from the cut flowers held in different floral preservatives was recorded as the parameters.

Data Analysis

The data was subjected to the analysis of variance according to Steel and Torrie (1960), and Snedecor and Cochran (1967). Data on the number of sprouted rhizomes, number of flowering shoots, number of marketable stems, were calculated in percentages. Some of these were transformed to arcsin, expressed in degrees to make variance of resulting observations relatively consistent (Steel and Torrie, 1960). A statistical analysis for each data was carried out with transformed data. Means were compared and separated by F values and Duncan's Multiple range test, respectively (Snedecor and Cochran, 1967; Steel and Torrie, 1960).

RESULTS

Shoot Growth

Percent shoot emergence from planted rhizomes was higher in 'Pink Perfection' than 'Carmen' and 'Marina' (Fig. 1). Differences were, however, insignificant at 5% level. First shoot emergence was observed on day 8, 9 and 10 from 'Pink Perfection', 'Carmen' and 'Marina', respectively (Table 1(a). Within 21 days, all planted rhizomes had sprouted.

There were varietal differences in the number of total shoot (flowering and non-flowering) produced (Fig. 2). Between planting (October) and the 26th week (April), the number of total shoots increased steadily, being more in 'Pink Perfection' than in 'Carmen' and 'Marina' in that order. Differences in shoot number were, however only significant (5% level) between the 16th week (February) and the 24th week (April). During this period, all shoots formed in 'Marina' and 'Pink Perfection' were blind (vegetative shoots that do not flower). The total number of shoots included both flowering and non-flowering shoots in 'Carmen' (Fig. 2). Optimum shoot production in 'Carmen' was reached around the 29th week (end of May)

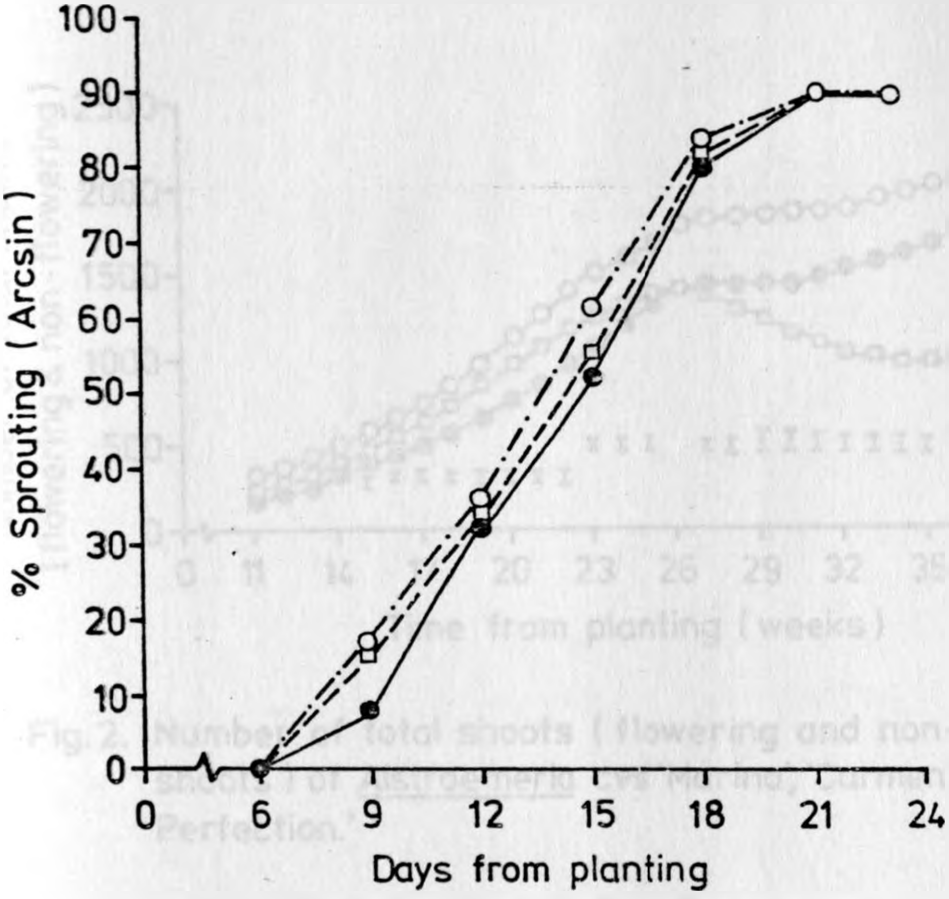

Fig. 1. The rate of sprouting from Alstroemeria rhizomes (percentages transformed to Arcsin).

●——● A. 'Marina'
□- - -□ A. 'Carmen'
○·—·○ A. 'Pink Perfection'

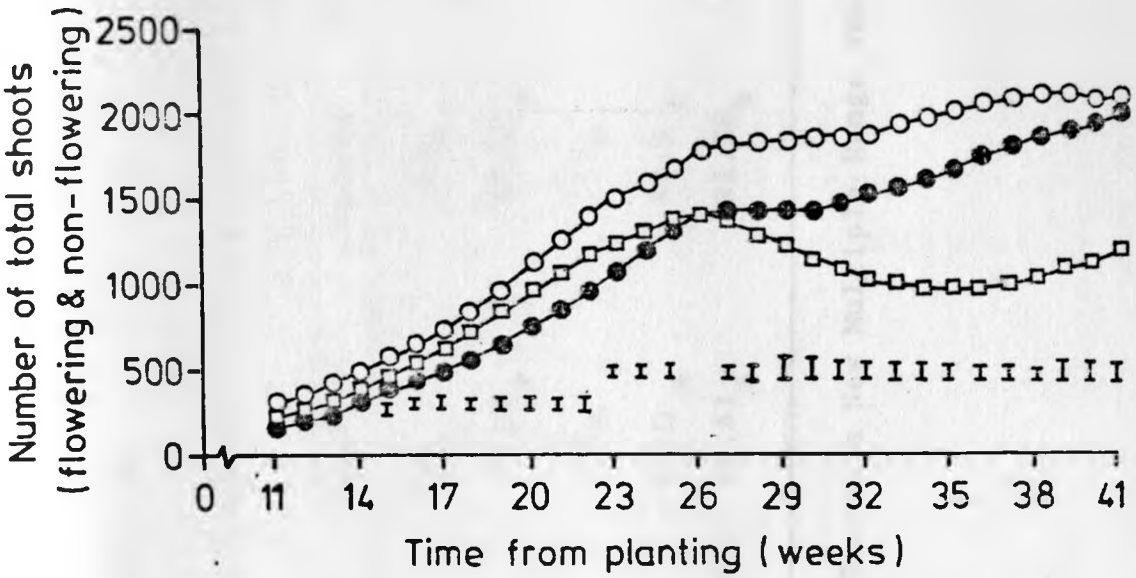

Fig. 2. Number of total shoots (flowering and non-flowering shoots) of Alstroemeria cvs 'Marina', 'Carmen' and 'Pink Perfection.'

□——□ Carmen; ○——○ Pink Perfection;
●——● Marina.
Vertical bars represent LSD at 5 % level.

Table 1(a). Growth and flowering of Alstroemeria

	CULTIVARS		
	'Carmen'	'Marina'	'Pink Perfection'
Days from planting to first sprouting	[z]10$_a$	10$_a$	9$_a$
Percent shoot emergence at day 21 (Arcsin)	90.00$_a$	90.00$_a$	90.00$_a$
Days from planting to flowering	132$_a$	245$_c$	215$_b$
Average length of flowering stems (cm)	47.0 $_a$	82.9 $_b$	94.3 $_b$
Percent marketable flowering stems (Arcsin)	42.41$_a$	82.38$_b$	89.32$_b$

[z]Mean separation within rows according to Duncan's New Multiple Range Test, 5% level.

with 1380 shoots in all the 12 hills, dropping afterwards with time, remaining relatively constant between the 35th and the 40th weeks at about 980 shoots in 12 hills. Total shoot production in 'Pink Perfection' and 'Marina' continued to increase with time, the rate being greater for the latter than the former (Fig. 2). Senescence in most shoots was noted in 'Carmen' after the 30th week (June).

Flowering

Days from planting to flowering varied significantly among the 3 varieties of Alstromeria used. 'Carmen', 'Pink Perfection' and 'Marina' flowered 132, 215 and 245 days after planting, respectively (Table 1(a)). The times of flowering corresponded to February, end of May and Mid-June for 'Carmen', 'Pink Perfection' and 'Marina', respectively (Table 1(a); Appendix AI).

There were significant varietal differences in the number of flowering shoots produced per week (Fig. 3). 'Carmen' produced the highest number of flowering shoots when hills were 32 weeks old. 'Carmen' also produced more flowering shoots than 'Pink Perfection' and 'Marina' in that order (Fig. 3).

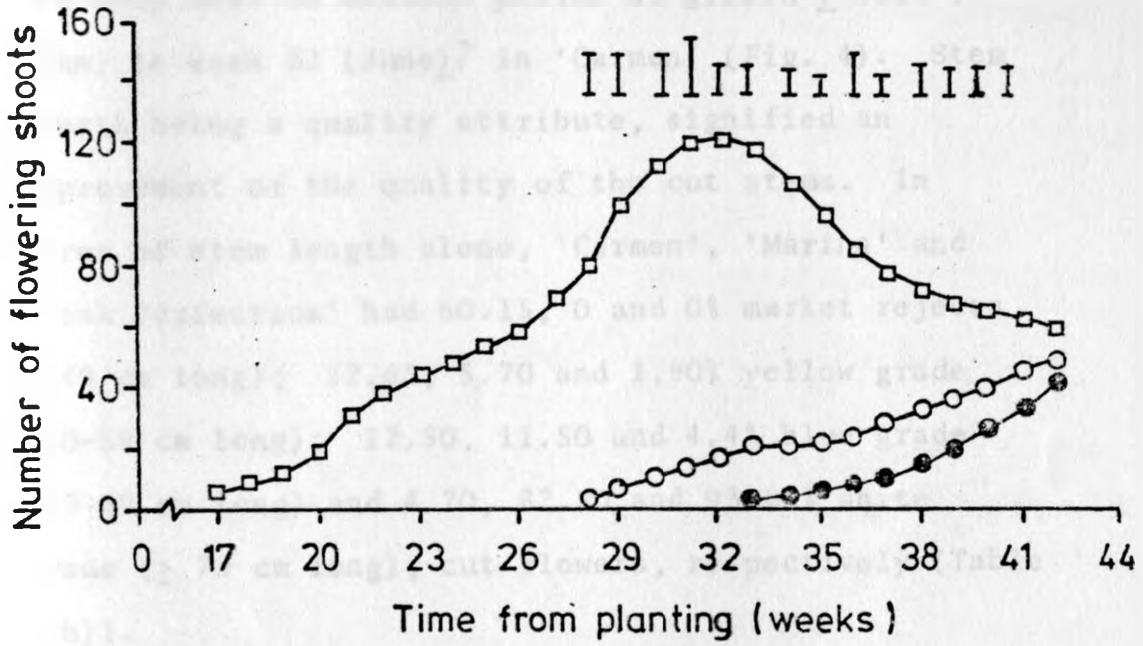

Fig.3. Number of flowering shoots of Alstroemeria cvs 'Carmen', 'Marina' and 'Pink Perfection'

Carmen; Pink Perfection; Marina.

Vertical bars represent LSD at 5 % level.

The average lengths of floral stems were 94.3, 82.9 and 47.0 cm in 'Pink Perfection', 'Marina' and 'Carmen', respectively (Table 1(a)). These lengths increased with time in 'Marina' and 'Pink Perfection' and only over an initial period of growth /Week 14 (Jan) to week 32 (June)/ in 'Carmen' (Fig. 4). Stem length being a quality attribute, signified an improvement of the quality of the cut stems. In terms of stem length alone, 'Carmen', 'Marina' and 'Pink Perfection' had 60.15, 0 and 0% market rejects (≤49 cm long); 22.65, 5.70 and 1.80% yellow grade (50-59 cm long); 12.50, 11.50 and 4.4% blue grade (60-69 cm long) and 4.70, 82.80 and 93.80% white grade (≥ 70 cm long), cut flowers, respectively (Table 1(b)).

The percentage of flowering shoots to total shoots (flowering and non-flowering shoots) followed the same trend as the number of flowering shoots in all the three Alstroemeria cultivars (Fig. 5). This reflected an increase in the ratio of flowering to non-flowering blind shoots during flowering.

The leaf angles and the number of leaves upto 15 cm below the cyme distinguished 3 types of shoots: the blind, unmarketable flowering and the marketable flowering shoots. The blind shoots had more leaves

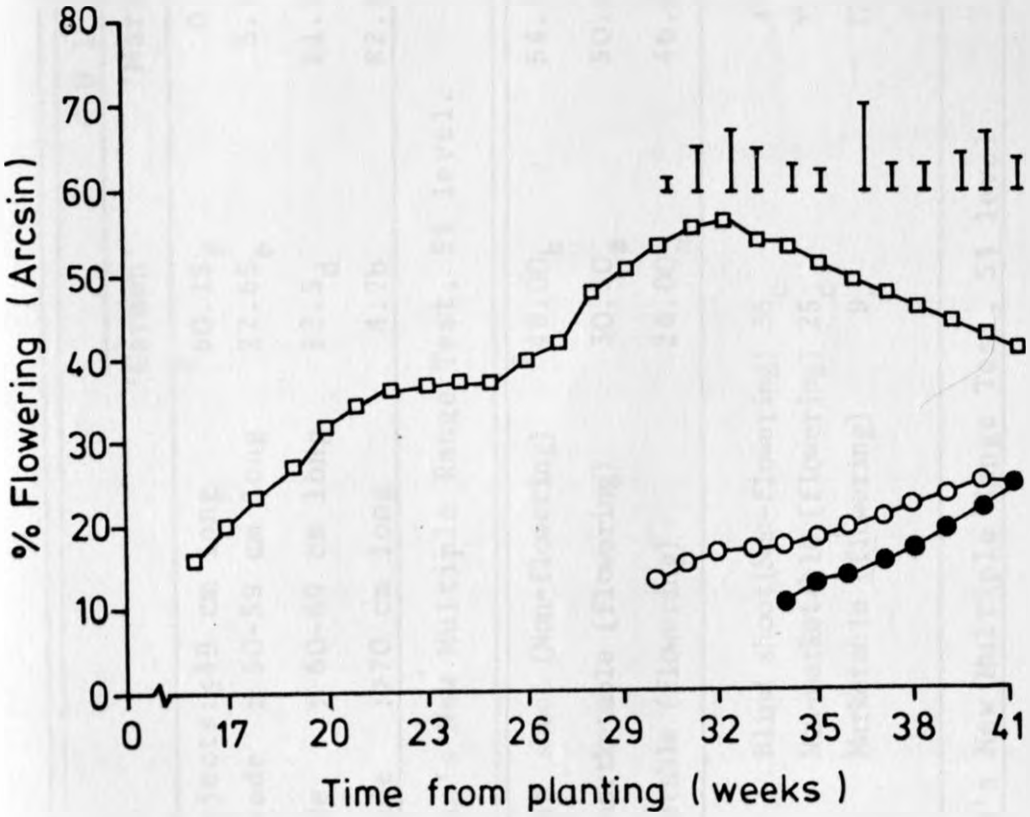

Fig. 4. Percent flowering of Alstroemeria cvs 'Carmen', 'Marina' and 'Pink Perfection' (Percentages transformed to Arcsin).

□——□ Carmen; ○——○ Pink Perfection;
●——● Marina.
Vertical bars represent LSD at 5% level.

Table 1(b). Quality characteristics and marketability of Alstroemeria cut flowers.

			CULTIVARS		
			'Carmen'	'Marina'	'Pink Perfection'
Percent graded flowers	Market rejects: ≤49 cm long		[z]60.15_f	0	0
	Yellow grade	: 50-59 cm long	22.65_e	5.7_c	1.8_a
	Blue grade	: 60-69 cm long	12.5_d	11.5d	4.4_b
	White grade	:>70 cm long	4.7b	82.8g	93.8g
Shoot morphology	Leaf angle (°)	Blind shoot (Non-flowering)	[z]48.00_b	54.50_c	54.80_c
		Non-martketable (flowering)	30.50_a	50.67_b	39.80_b
		Marketable (flowering)	26.00_a	46.00_b	29.00_a
	Leaf number on 15 cm of flowering stem below the cyme.	Blind shoot(Non-flowering)	36_c	44_d	47_d
		Non-marketable (flowering)	25_c	27_b	29_b
		Marketable (flowering)	9_a	12_a	12_a

[z] Mean separation by Duncan's New Multiple Range Test, 5% level.

[z] Mean separation by Duncan's New Multiple Range Test, 5% level

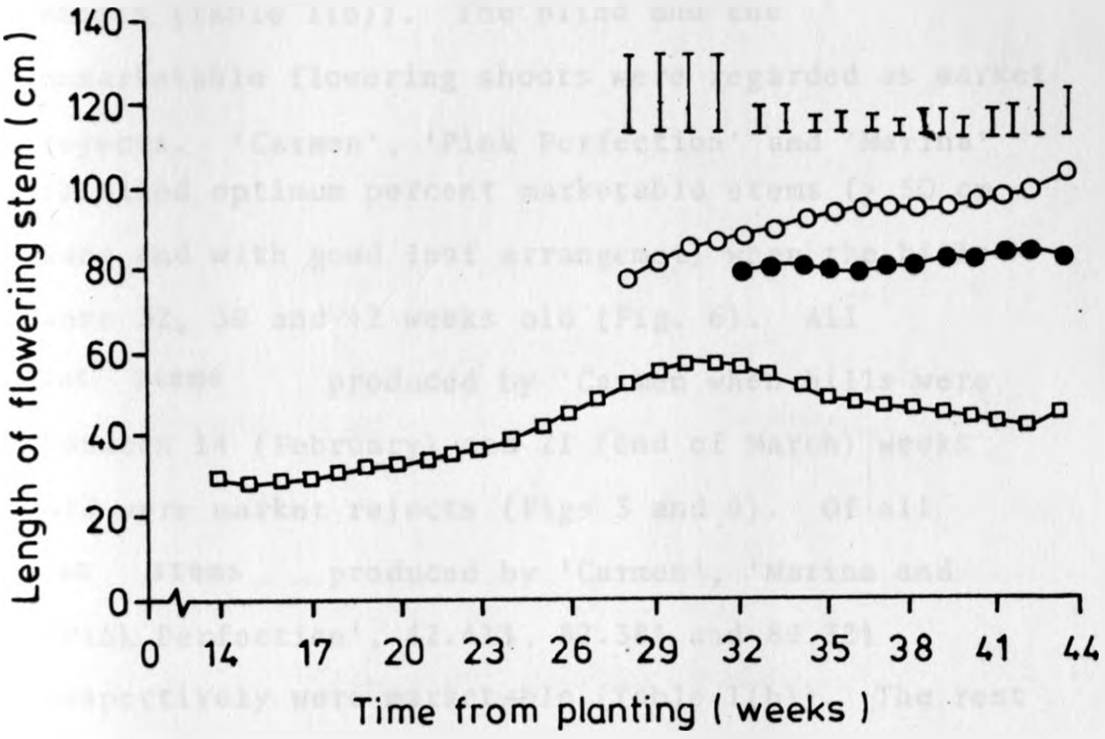

Fig. 5. Average length of flowering stems (cm) in Alstroemeria cvs 'Carmen', 'Marina' and 'Pink Perfection.'

□——□ Carmen; o——o Pink Perfection;
●——● Marina.
Vertical bars represent LSD at 5 % level.

and wider leaf angles on the floral stem than the unmarketable flowering and the marketable flowering shoots (Table 1(b)). The blind and the unmarketable flowering shoots were regarded as market rejects. 'Carmen', 'Pink Perfection' and 'Marina' obtained optimum percent marketable stems (≥ 50 cm long and with good leaf arrangemet) when the hills were 32, 39 and 42 weeks old (Fig. 6). All cut stems produced by 'Carmen when hills were between 14 (February) and 21 (end of March) weeks old were market rejects (Figs 3 and 6). Of all cut stems produced by 'Carmen', 'Marina and 'Pink Perfection', 42.41%, 82.38% and 89.32% respectively were marketable (Table 1(b)). The rest were market rejects

Shoot Pruning of Alstroemeria cv. 'Marina'

Pruning had no influence on the number of total shoots produced in Alstroemeria cv 'Marina' (Fig. 7). The number of total shoots from unpruned hills were significantly more than from the pruned ones for the first 9 weeks after pruning (Fig. 7). This difference in the number of total shoots became insignificant after the 9th weeks from the time of pruning. Pruning however, promoted the production

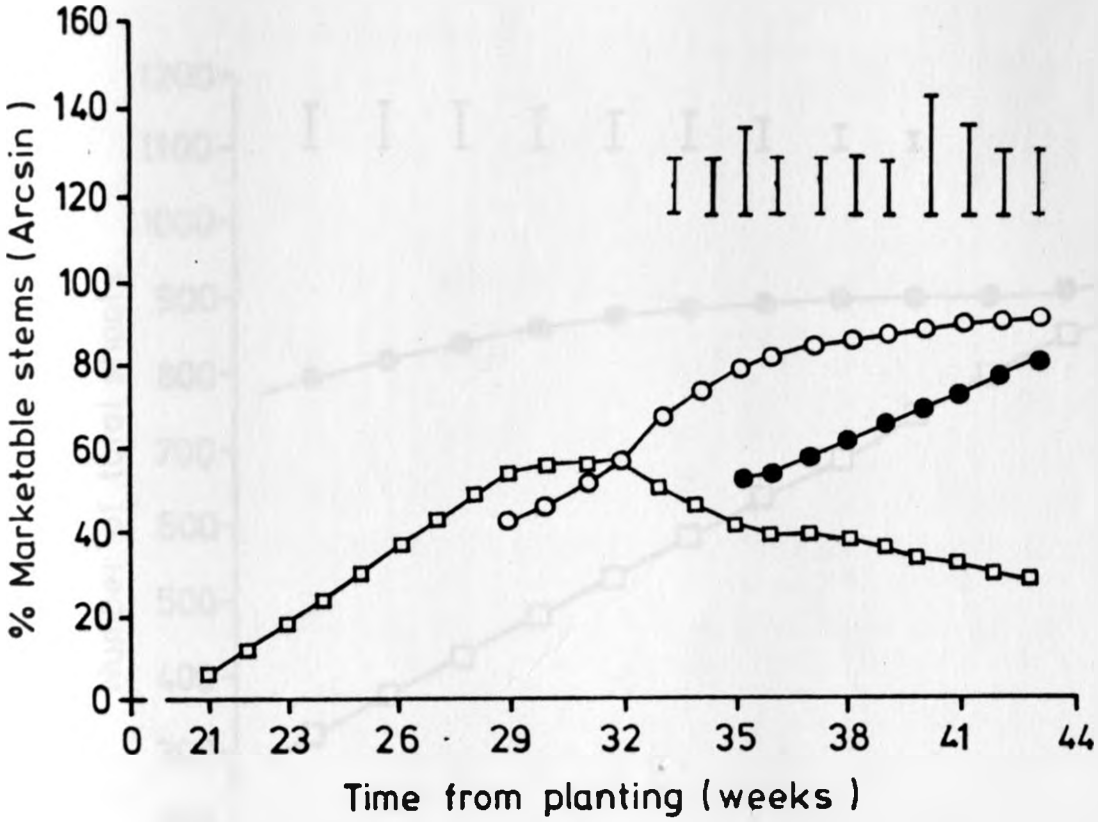

Fig. 6. Percent marketable stems of Alstroemeria cvs 'Carmen', 'Marina' and 'Pink Perfection' (percentages transformed to Arcsin).

□—□ Carmen; ○—○ Pink Perfection;
●—● Marina.
Vertical bars represent LSD at 5 % level.

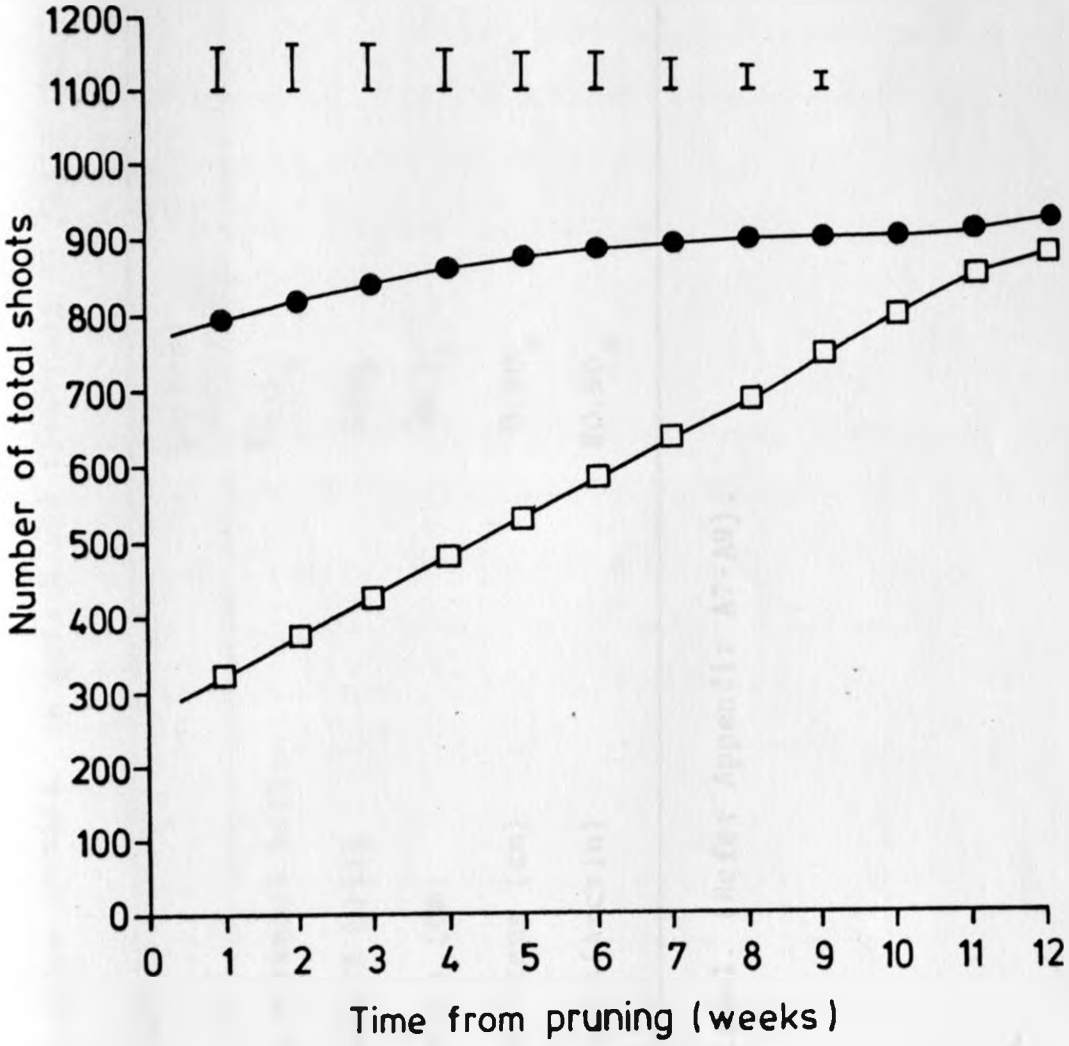

Fig. 7. Effects of pruning on number of total shoots of Alstroemeria 'Marina'.

●——● Control.

□——□ Pruned.

Vertical bars represent LSD at 5 % level.

Table 2(a). The effect of shoot pruning on growth and flowering of Alstroemeria 'Marina'.

	Control (unpruned)	pruned
Total number of new shoots formed/5 hills	$^{z}201_{a}$	569_{b}
Total number of floral stems/5 hills	120_{a}	181_{b}
Average length of floral stems (cm)	96.2_{a}	119.6_{b}
Average diameter of floral stems (cm)	0.90_{a}	1.07_{b}
Percent marketable cut flowers(Arcsin)	80.90_{a}	81.87_{a}

^{z}Means compared at F, 5% level. (Refer Appendix A7-A9).

of new shoots (Fig. 8, Table 2a). The total number and percentage of new shoots were significantly more in pruned hills than the unpruned ones (Table 2a). The average rates of shoot formation were 47.42 and 16.75% in pruned hills and unpruned ones, respectively (Figure 8).

The number of cut flowers produced from pruned hills were more than from unpruned ones. (Fig. 9). Their marketability was, however, not affected (Table 2a). The total number of cut stems from pruned hills were 50.83% more than the unpruned ones (Table 2a). The average lengths of cut flowers were 119.6 cm and 96.2 cm from pruned and unpruned hills, respectively (Table 2a). The average diameters were 1.07 and 0.90 cm in pruned hills and the controls respectively (Table 2a). Although pruning had no influence on the percent marketable floral stems, more white grade cut stems ($\geq$ 70 cm long) and less blue (60-69 cm) and yellow (50-59 cm long) were produced from pruned hills compared to the controls (Table 2 b).

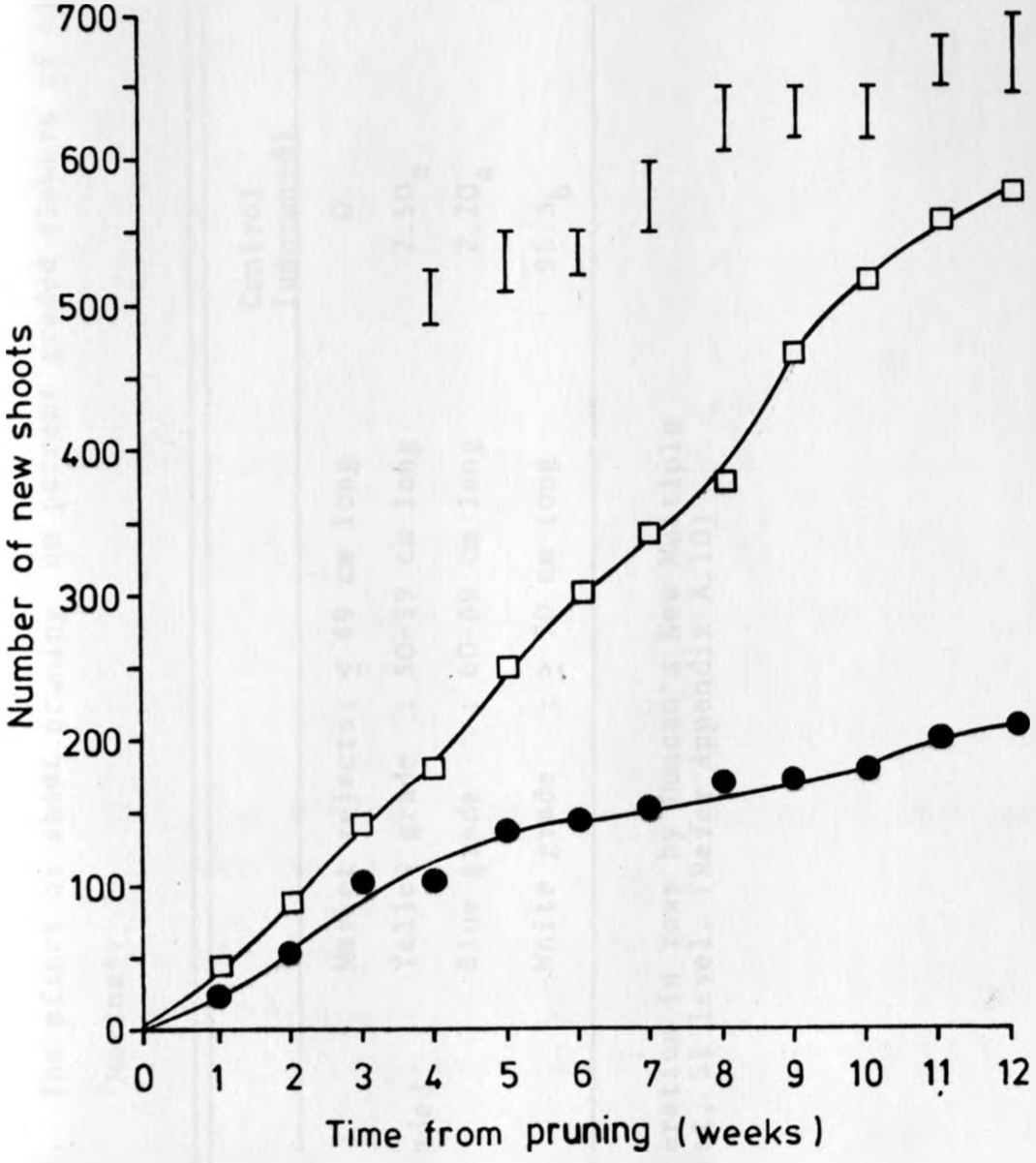

Fig. 8. Effect of pruning on the number of total new shoots of Alstroemeria 'Marina'

●—● Control.

□—□ Pruned.

Vertical bars represent LSD at 5% level.

Table 2(b). The effect of shoot pruning on percent graded flowers of Alstroemeria 'Marina'.

		Control (unpruned)	Pruned
Percent graded flowers	Market rejects: ≤ 49 cm long	0	0
	Yellow grade : 50-59 cm long	2.50_a	1.01_a
	Blue grade : 60-69 cm long	2.20_a	1.19_a
	White grade : ≥ 70 cm long	95.3_b	97.8_b

Ž Mean separation in rows by Duncan's New Multiple Range Test, 5% level. (Refer Appendix A.10)

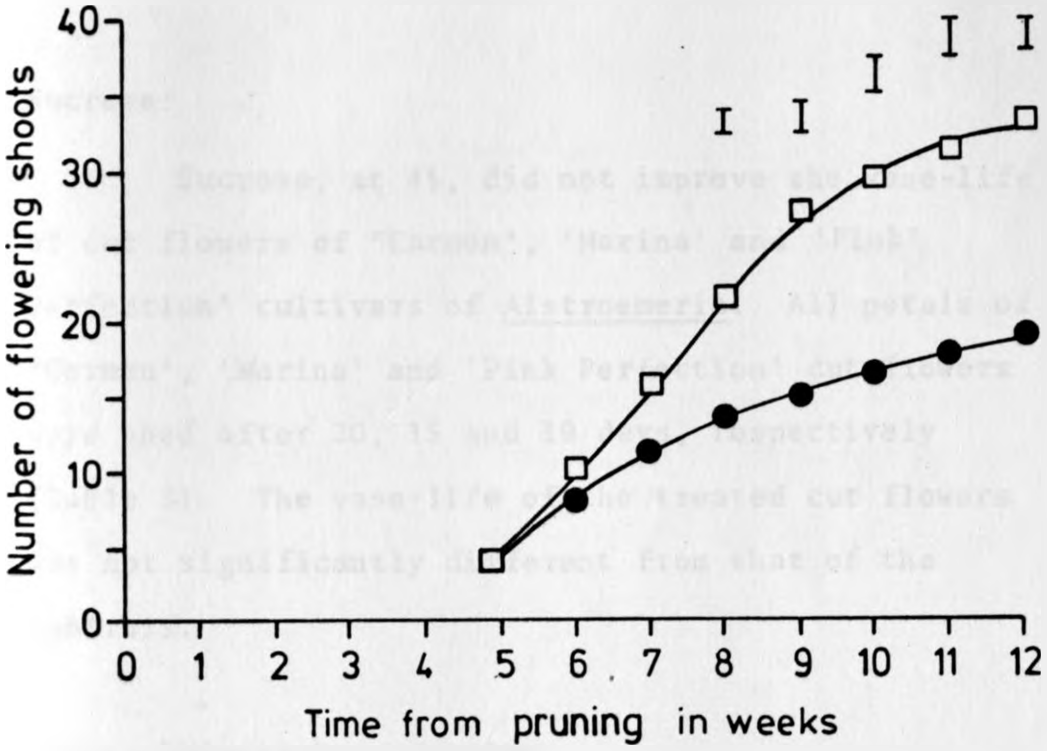

Fig. 9. Effect of pruning Alstroemeria 'Marina' on number of flowering shoots.

●——● Control.

□——□ Pruned.

Vertical bars represent LSD at 5 % level.

Effect of Floral Preservatives on the Vase-life of *Alstroemeria* cut flowers

Sucrose:

Sucrose, at 4%, did not improve the vase-life of cut flowers of 'Carmen', 'Marina' and 'Pink' Perfection' cultivars of *Alstroemeria*. All petals of 'Carmen', 'Marina' and 'Pink Perfection' cut flowers were shed after 20, 15 and 19 days, respectively (Table 3). The vase-life of the treated cut flowers was not significantly different from that of the controls.

Silver Thiosulphate Complex:

The vase-life of cut flowers of *Alstroemeria* cvs 'Carmen', 'Marina' and 'Pink Perfection' treated for 1 hour in a silver thiosulphate complex, then transfered to deionized water was improved. The shedding of petals occurred after 29, 26 and 22 days in 'Carmen', 'Pink Perfection' and 'Marina', respectively. The vase-life of the cut-flowers was therefore increased by 8, 7 and 6 days in 'Carmen', 'Pink Perfection' and 'Marina', respectively compared to the controls (Table 3). Those transfered to 4%

Table 3. Effect of floral preservatives on the vase-life of Alstroemeria cut-flowers

Cultivar	PRESERVATIVES					
	Control (Deionized water)	4% sucrose	Silver thio-sulphate compled	Silver thio-sulphate complex 4% + sucrose	2.5% Chrysal	2.5% Chrysal 4% + sucrose
'Carmen'	21_a	20_a	29_b	27_b	30_c	26_b
'Marina'	16_a	15_a	22_c	18_b	22_c	18_b
'Pink Perfection'	19_a	19_a	26_c	23_b	26_c	23_c

z Mean separation within rows by Duncan's New Multiple Range Test, 5% level. (Refer Appendix A.11).

sucrose shed all petals after 27, 23 and 18 days showing a vase-life increase of only 6, 4 and 2 days compared to the controls in 'Carmen', 'Pink Perfection' and 'Marina', respectively (Table 3).

Chrysal:

The vase-life of cut flowers of Alstroemeria cvs 'Carmen', 'Pink Perfection' and 'Marina', treated for 1 hour in 2.5% chrysal, then transfered to deionized water was also improved. The shedding of all petals occurred after 30, 26 and 22 days in 'Carmen', 'Pink Perfection' and 'Marina' cut flowers, respectively (Table 3). The vase-life of 'Carmen', 'Pink Perfection' and 'Marina' cut flowers was, therefore, increased by 9, 6 and 6 days respectively, compared to the controls. Those transfered to 4% sucrose solution shed all their petals after 26, 23 and 18 days in 'Carmen', 'Pink Perfection' and 'Marina', respectively (Table 3). The vase-life of 'Carmen', 'Pink Perfection' and 'Marina' cut flowers was, therefore increased by 5, 4 and 2 days respectively, compared to the controls.

There were no significant differences between silver thiosulphate complex and chrysal treatments in improving the vase-life of Alstroemeria cut flowers in all cultivars used. Floral stems held in silver

thiosulphate complex or chrysal solutions for 1 hour, then transfered to deionized water, generally had the best improvement on vase life. 'Carmen', and 'Pink Perfection' cut flowers had longer vase lives than those of Marina in all treatments (Table 3).

DISCUSSION

Growth and Flowering

The growth and flowering of Alstroemeria consisted of distinct but overlapping vegetative and reproductive phases. The 3 Alstroemeria cultivars 'Carmen', 'Marina' and 'Pink Perfection' varied in their growth and flowering performances as affected by prevailing, environmental conditions. 'Regina' and 'Orchid' ('Walter Fleming') cultivars of Alstroemeria were similarly reported to perform differently in the Netherlands, United States of America and Canada, in relation to growth and flowering (Molnar, 1975).

The number of total shoots (flowering and non-flowering) produced by all cultivars increased with time between October (planting time) and mid-May (week 29). All shoots produced by 'Marina' and 'Pink Perfection' during this period were vegetative shoots that could not flower (blind shoots). However, most shoots produced by 'Carmen' flowered. Between the end of May (week 31) and August (week 43) the total shoot production continued to increase in 'Marina' and 'Pink Perfection', but decreased in 'Carmen'. The proportion of vegetative to flowering shoots however decreased in 'Marina' and 'Pink Perfection' during this period (weeks 31-43). This is because the shoots formed during

this period flowered in these two cultivars. Between September and April, daily temperatures in Limuru ranged between 20.3°C in January while between the end of May and August, daily temperatures averaged 17.1°C in July and 20.0°C in May with corresponding night temperatures of 8.6°C and 11.5°C respectively. Vegetative shoot formation in 'Marina' and 'Pink Perfection' is proposed to have been promoted by the relatively high temperatures between November (Week 1) and the end of March (week 22), and retarded by the low day and night temperatures between May and August period. These observations are comparable to those reported by Heins and Wilkins (1976, 1979), and Vonk Noordegraaf (1975) working on 'Orchid' and 'Regina' cultivars of Alstroemeria. Vegetative shoot formation in 'Orchid' cultivar was stimulated by high air temperatures (25°C) and inhibited by low air temperatures (9-17°C) (Heins and Wilkins, 1979; Vonk Noordegraaf, 1975). Heins and Wilkins (1979), similarly reported that high soil temperatures (21°C) also stimulated vegetative shoot growth in 'Regina' while low temperatures (15°C), inhibited it. Soil temperatures in Limuru may drop as low as 6°C between May and August. Vonk Noordegraaf (1975) further demonstrated that 9°C day temperature promoted a greater

ratio of flowering to vegetative blind shoots in 'Regina' while 25°C gave the opposite results. This observation on 'Regina' similarly corresponds to the decreasing proportion of vegetative to flowering shoots observed in 'Marina' and 'Pink Perfection' during and after the cooler period between May and August.

Most of the shoots produced in 'Carmen' flowered all year round. The prevailing temperatures could, therefore, have been favourable for flowering of 'Carmen'. Between November (week 1) and mid-May, (week 32) the number of flowering shoots in 'Carmen' increased with time reaching optimum production in May. Total shoot production then decreased during the cool period between June (week 32) and August (week 44) as a result of heavy shoot senescence. Excessive flowering in 'Carmen' could also have depleted assimilates resulting in senescence. Out of 1832 total shoots produced on 12 hills over the entire experimental period, only 10 were blind, the rest flowered. Between week 1 (November) and week 31 (mid-May), flowering in 'Marina' and 'Pink Perfection' was completely inhibited and all shoots formed were blind. Flowering stems of these 2 cultivars were first harvested at the end of May (week 30). The number of flowering shoots and the quality (stem

length and leaf arrangement) of inflorescences increased with time during flowering. Flower induction in 'Marina' and 'Pink Perfection' is proposed to have been promoted as early as April during the rains when temperatures were starting to drop. The cool June-July temperatures are suggested to have been very conducive for flower induction. As suggested by Healy and Wilkins (1979), the rhizome could have been the receptor site of floral stimuli which is the cool temperature. All new shoot formed, just before or during the cool period between May and August flowered because the soil temperatures were adequately low to induce flowering of those shoots. Results obtained on the flowering of 'Marina' and 'Pink Perfection' are comparable to those reported by Heins and Wilkins (1976, 1979), Molnar (1975) and Vonk Noordegraaf (1975) working on 'Orchid' and 'Regina' cultivars of Alstroemeria. They reported that flowering of 'Orchid' was induced by low temperatures (9-13^{o}C) and inhibited by high soil temperatures (>25^{o}C). The flowering of 'Regina' was induced by low soil temperatures (15^{o}C) and ihibited by high soil temperatures (>21^{o}C). This could be a possible explanation for the observed inhibited flowering in

'Marina' and 'Pink Perfection' during the warmer period between November and February, and the promoted flowering during and after the cool May-September period in Kenya. Soil temperatures in Limuru are between 6-12^{o}C during that cool period. Time of planting could also influence the time taken from planting to flowering and the amount of flowering stems produced. Rhizomes planted during the April long rains could be induced to flower by the cool May-July temperatures. The amount of flowering would however be small due to slowed overall growth due to the low temperatures. The rhizome growth and branching would not be as advanced as of those plants planted during the short rains of October-November. Irrigation should however supplement the rains.

Although as explained above, 'Carmen' flowered most of the time and produced more flowering shoots than 'Marina' and 'Pink Perfection', the quality of inflorescences was more inferior, especially in terms of stem length. Percent marketable stems ($\geq$ 50 cm long, good leaf arrangement) in 'Carmen' increased under irrigation during the dry period between January and March when daily temperatures were between 23 and 25^{o}C. Inflorescences produced by 'Carmen' during

the first month of flowering (weeks 16-20) were unmarketable due to the short stem length. The percent marketable stems then increased until senescence set in around week 32 when it decreased during the cooler period of June (week 34) to August (week 44). Differences in flowering and quality of inflorescences were small for 'Marina' and 'Pink Perfection'. This means that their growth and flowering responses to environmental conditions were fairly similar. 'Marina and 'Pink Perfection' produced more marketable stems. In terms of stem length alone, all shoots produced by the 2 cultivars were marketable ($\geq$ 50 cm long). It was however observed that some of the flowering shoots had more and relatively closer spaced leaves just below the cyme than other flowering shoots. The leaf angles were noted to be wider in blind shoots followed by flowering unmarketable shoots, then the flowering marketable ones. These leaf angles were averaged over the first 4 leaves below the cyme, since the angle decreased along the same floral stem below the cyme. It is possible that the cooler temperatures around June-July promoted stem elongation and flower induction, resulting in longer stems with fewer widely spaced leaves with narrow leaf angles compared to the

warmer temperatures especially between December and March. By September, most of the shoots produced in 'Pink Perfection' flowered, producing 100% marketable floral stems. This was not achieved in 'Marina' which recorded a maximum of 90% marketability.

In the Netherlands, 'Orchid' and 'Regina' cultivars of Alstroemeria had 2 main flowering periods annually: spring (May) when average daily temperatures are about 10-14.5°C and fall (August, September, October) when average daily temperatures are about 10-18°C (Molnar, 1975). That temperature range is comparable to the Limuru (Kenya) temperatures during the cooler period between May and August. Flower induction in the United States of America and Canada are restricted to spring and early summer (Heins and Wilkins, 1976). Later during summer, temperatures are higher than 25°C in those countries. Flowering of Alstroemeria as reported earlier, is inhibited by those high temperatures.

Temperature requirements for flowering in orchids were similarly reported to vary with cultivars (Sheehan, 1980). Cymbidium orchids required night temperatures of 10°C for flower induction. An average of 10°C night and 21-24°C day temperatures were ideal for flowering of Cymbidium orchids (Sheehan, 1980).

Cattleya species and its hybrids however flowered best at higher night temperatures between 15.0 and 18.0°C compared to Cymbidium orchids. Phalaenopsis, especially the white flowered cultivars, grew best at 18.0°C night and upto 27.0°C day temperatures (Sheehan, 1980). Pink Phalaenopsis cultivars, however, flowered better when night temperatures were 13-15°C (Sheehan, 1980).

Besides temperature, daylength has been reported to influence growth and flowering of Alstroemeria and other cut-flowers. The average daylength in Kenya is 12 hours. 'Carmen', 'Marina' and 'Pink Perfection' flowered under prevailing daylengths. Heins and Wilkins (1979), Lin and Molnar (1984), Molnar (1975) and Vonk Noordegraaf (1975) reported that long photoperiods (≥ 12 hours) stimulated earlier flowering in Alstroemeria while short ones (8 hours) inhibited flower production. 'Regina' cultivar produced 20% more floral stems per plant which were taller when grown under long photoperiods (16 hours) than under short photoperiods (8 hours) (Molnar, 1975). Plants grown under long daylength (16 hours) flowered 6 weeks earlier and had 30% more flowering shoots compared to those grown under short days (Healy and Wilkins, 1979; Molnar, 1975). 'Regina' outyielded 'Orchid' by more than 40% on a plant to plant basis

when grown under long day (16 hours) condition (Molnar, 1975).

The average 12 hour daylength in Kenya has proved sufficient for flowering of Alstroemeria, provided the temperatures are conducive for flower induction and initiation. This is in agreement to the observations by Heins and Wilkins (1979) that there were no indications that photoperiodic treatments could substitute for cold treatment for flower induction in Alstroemeria as was shown in Dicentra (Lopes and Weiler, 1977) and Lilium longiflorum Thunb (DeHertogh, et al., 1969; Weiler and Langhans, 1976). They suggested that there was a phasic flowering mechanism in Alstroemeria where thermophase must precede photophase. Plants would therefore induce and initiate flowers during the cool rainy season, then flower during periods of warmer temperatures and long photoperiods until too high temperatures inhibit flowering (Heins and Wilkins, 1979).

During the cool June-July period, heavy shoot senescence in 'Carmen' was noted. Heins and Wilkins (1979) reported that when Alstroemeria were grown at temperatures less than 15^{o}C, there was increased storage root growth and enlargement.

A marked increase in rhizome to shoot growth ratio was similarly observed when Agropyron was grown at 15°C compared to 25°C (McIntyre, 1970). Poa pratensis plants grown at 13°C exhibited greater root storage growth compared to those growth at 18°C or 24°C (Mckell, et al., 1969). Heins and Wilkins (1979), proposed that starch in storage organs (tuberous roots) was a possible source of carbon for rapid flower shoot development. Thus the thermophase may depress shoot growth while stimulating root filling. This could be a possible explanation for the noted shoot senescence in 'Carmen' when temperatures decreased during the cool period between May and August. Long photoperiods (≥ 12 hours) may also enhance plant growth substances relationships within Alstroemeria that could be promoting flowering (Healy and Wilkins, 1982).

Shoot Pruning of Alstroemeria

Shoot pruning is a major horticultural practice beneficial for successful production of many ornamental plants (Edmond et al., 1977).

Shoot pruning promoted the production of new shoots in Alstroemeria. In roses, pruning by cutting off branching stems similarly promoted growth of many lateral shoots which became strong sinks of metabolites

(Kohl, et al., 1967; Mor and Halevy, 1979). Pruning of Alstroemeria aerial shoots could have increased the growth of the main rhizome. Removal of an old shoot above the soil stimulates the growth of the auxillary bud on the second scale leaf of the removed shoot. This bud has the potential to become a new rhizome (Heins and Wilkins, 1979). The increased rhizome branching could have resulted into the formation of more new aerial shoots.

Pruning of Alstroemeria had no influence on the time of flowering. Shoot pruning however improved the number and quality (stem length and diameter) of cut floral stems. Pruning has been similarly reported to improve flowering and quality of inflorescences in other ornamentals. Rose pruning improved flower production and produced canes with larger diameter and longer stemmed flowers (Laurie et al., 1980). Abundant lateral shoots and flowers were obtained by pruning begonias (Larson, 1980). This had to be controlled because crowding resulted in poorly formed, excessively succulent and tall plants with higher disease incidence (Larson, 1980).

Pruning of Alstroemeria was done in June. As explained earlier, flowering of Alstroemeria was

probably promoted by low temperatures during the cool period between May and August.

The young shoots that were not pruned and the new shoots formed after pruning flowered due to prevailing conducive conditions for flowering during the cool June-July period. As observed earlier, all shoots formed during the dry warm period of the year were blind. Shoot pruning at this time could only reduce competition for space and nutrients. Pruning plants during the dry season could not promote flowering since the high temperatures are not conducive for flowering.

The total number of shoots per hill 9 weeks after pruning were the same in pruned and unpruned hills. The resulting shoot overcrowding produced leggy, crooked shoots which were not marketable. This indicated that shoot thinning practiced by farmers could be more beneficial by removing the tall leggy stems and the crooked ones. Fewer, strong and straight marketable stems would be produced.

Greenhouse grown Stephanotis floribunda L. that had excess or dense vine growth were less apt to flower because of shading of lower leaves (Kofranek and Kubota, 1981). Severe pruning in

spring developed new vine growth that was receptive to extended photoperiod for flower induction (Kofranek and Kubota, 1981).

Effect of Floral Preservatives on the Vase-life of Alstroemeria

Sucrose:

Sucrose has been reported to improve the vase-life of various cut-flowers: roses (Sacalis, 1973); Carnation (Aarts, 1957; Amariutei and Burzo, 1981; Halevy and Mayak, 1974; Larsen and Frolich, 1969; Nichols, 1969; 1973; Sacalis, 1973); gladiolus (Bravdo, et. al., 1974; Halevy and Mayak, 1974; Mayak et. al., 1973) and Chrysanthemum (Kofranek and Halevy, 1972). However, in this study, sucrose did not improve the vase-life of Alstroemeria cut flowers. Petals of all cut flowers of 'Carmen', 'Marina' and 'Pink Perfection' cultivars were shed at the same time as the controls. Similar results were reported by Nichols (1973) working on Narcissus cut flowers. Nichols (1973) observed that sucrose slightly improved the vase-life of Narcissus cut flowers but resulted in substantial growth of the ovary.

The sucrose effect on the senescence of cut flowers was reported to be determined by the predominant sugar content in the corolla and the relative

corolla and ovary sink strengths (Nichols, 1973). During senescence of Narcissus cut flowers cv 'Actaea', the ratio of reducing sugars to sucrose concentrations depended on the stage at which the flower was cut (Nichols, 1973). Nichols (1973) observed that when the cut flower was cut at the goose-neck stage (when the bud is reflexed at right angles to the stem), reducing sugars in the bud increased to a maximum. This roughly coincided with the full flower opening. The reducing sugars, however decreased at harvesting until half the maximum content remained at wilting of the corolla. When the flower opened, sucrose disappeared while reducing sugars were accumulating in the corolla. The large amounts of residual pool of reducing sugars at incipient wilting point led Nichols (1973) to suggest that corolla wilting in Narcissus cut flowers was not caused by depletion of respiratory substrate. The evidence suggested that in Narcissus and probably in Alstroemeria cut flowers, there was a continuous movement of sugars and water to the ovary. That means the ovaries of Narcissus and Alstroemeria flowers are stronger sinks of sugars than the corollae.

Nichols (1973) postulated that sugar had a

greater effect on the water relations of the Narcissus ovary than that of the corolla, since the ovary continued to grow long after the corolla had abscissed. The sucrose could have contributed to the osmotic potential of the ovary tissues, thereby improving their water content. It was further suggested that the effect of the osmotic potential was brought about by maintaining mitochondrial membrane integrity (Coorts, 1973; Sacalis, 1973) or by enhancing cuticle synthesis (Sacalis, 1973) of the corolla or the ovary. Sucrose could have also acted as an energy source of respiration and a basic metabolite for the Alstroemeria ovary as reported in other plant tissues (Coorts, 1973; Rogers, 1973).

Sucrose in carnations was, however, translocated to the corolla and hence the delay of their senescence (Nichols, 1973). Treatment with ethylene diverted the movement of sugars to the ovary, and therefore promoted senescence of the corolla (Nichols, 1973). Ethylene synthesis promoted corolla senescence. Thus, it was proposed that the relative sink strengths of the ovary and the corolla may be as important as the actual sugar concentrations in accounting for the apparent differences in response to exogenous sucrose

among cut flowers (Nichols, 1973).

Silver:

The vase-life of Alstroemeria cut flowers treated for 1 hour in silver thiosulphate complex solution made up of 0.2 mM silver nitrate and 1.6 mM sodium thiosulphate, then held in deionized water or in 4% sucrose vase solutions was improved. The shorter vase-life of those cut flowers held in 4% sucrose compared to that of those held in deionized water could be due to possible increased translocation of sugars to the ovary as reported earlier. This could have resulted to relative higher concentration of sugars in the ovary. Faster translocation of water from the petals to the ovary could have resulted in the shorter vase-life of the cut flowers.

Silver thiosulphate complex has been similarly reported to improve the vase-life of carnation cut flowers, the effect being greater on standard than spray carnations (Veen and Geijin, 1978; Nichols, 1973). Short pulses of silver thiosulphate complex were sufficient to double the normally one week long vase-life of carnation cut flowers (Sytsema, 1980; Reid, et. al., 1980; Veen, 1979). The vase-

life of Lilium longiflorum L. 'Enchantment' was longer by about 3 days after silver thiosulphate complex was used as a preservative, and more flowers reached full bloom (Swart, 1980). A silver thiosulphate pretreatment in Gladiolus similarly increased the percentage of florets which opened (Farnharm et al., 1980).

Chrysal a carrier of silver thiosulphate complex, containing gibberellic acid and a fungicide (benlate) had a similar effect on the vase life of Alstroemeria cut flowers as the straight silver thiosulphate complex. Similar observations have been reported in carnations (Salinger, 1973) and Gerbera (Bakker and Elst, 1958) cut flowers. Chrysal at 1.25% delayed 50% and complete senescence of carnation cut flowers (Salinger, 1973). Gerbera cut flowers held in 1.20% chrysal lasted longer than those held in water.

Several suggestions have been made on the possible role of silver ions in the senescence of cut flowers. The silver ion from silver thiosulphate complex could be acting as a biocide at the floral stem base (Aarts, 1957; Kafranek and Paull, 1973). The silver ion (Ag^{+}) could therefore reduce or eliminate bacterial build up in the

vascular tissue of the cut floral stems (Duckin and Kuc, 1966; Halevy and Mayak, 1981; Kofranek and Paul-, 1973; Paull and Goo, 1985). The Ag^{+} could also be interfering with wound ethylene binding sites (Sisler, 1982) at the stem base and therefore the ethylene promotive effect on senescence is delayed. The silver ions could also interfere with physiological blockage in cut stems, earlier explained to be caused by ethylene induced would gums. The water uptake from the stem base to the flowers is therefore increased. This would minimize water stress in the leaves and floral parts, and therefore improving the vase-life of cut flowers. The silver ion from silver thiosulphate complex was proposed to reach the ethylene receptor sites through the xylem vessels, suggesting that the active sites were probably in cell walls and or on the surface of adjacent plasma membranes (Todaka et. al., 1978; Liebermann, 1979; Veen et. al., 1980). Irrespective of the site, the major response was an apparent maintenance of stem water uptake (Paull and Goo, 1985). The rate of water uptake from cut Anthurium and probably in Alstroemeria flowers decreased steadily after harvest, with the silver treated cut flowers having an increased rate of water uptake late in flower life (Paull and Goo, 1985). The

water balance and longevity of cut flowers was therefore maintained for a longer period in silver treated compared to non silver treated cut flowers. Similar patterns have been reported in roses and carnations (Camprubi and Fontarnau, 1977; Duckin and Kuc, 1966; Mayak, et. al., 1973).

Silver thiosulphate complex, applied to carnation floral stem bases was transported quickly to the flower (Veen and Geijn, 1978)where it interfered with ethylene production. This resulted to reduced senescence of carnation cut flowers. Silver thiosulphate complex, applied to Alstroemeria cut flowers could have had the same effect as in carnations, resulting in improved vase-life. The reduction of ethylene production by silver ions ensure that the physiological and biochemical effects of ethylene in accelerating senescence of cut flowers were reduced. Some of these effects, as explained earlier, include increased respiratory activity, increased cell permeability, loss of cell compartmentalization and alteration of auxin transport and metabolism (Pratt and Goeschl, 1969). Some of the morphological effects of ethylene include in-rolling of petals, fading, wilting and abscission of flowers, epinasty and abscission of leaves (Kader, 1985).

Silver ions were proposed to react with ethylene to form a complex (Yang, 1985), but such a simple effect of silver has been ruled out as a sole possible mechanism of action. The exact mechanism by which they block or reduce ethylene action from promoting floral senescence and abscission still remains unknown (Yang, 1985). The effectiveness of the silver ion in reducing ethylene action declined with increasing ethylene concentration. It was assumed that one or more of the coordinating Ligands (L) in the receptor site facilitated the binding of ethylene to the receptor. This resulted in a biologically active complex that could be utilized by the plant cells during metabolism (Yang, 1985). Applied silver ion interacted with these coordinating Ligands resulting in the receptor having little capacity to bind ethylene.

CONCLUSIONS AND RECOMMENDATIONS

Temperature was one of the most important environmental factors that controlled growth and flowering of Alstroemeria. 'Carmen' cultivar flowered most of the time during the year, irrespective of daily temperature changes. It exhibited a higher production of cut flowers of poorer market quality compared to 'Marina and 'Pink Perfection'. Flowering in 'Carmen' occurred in February, a few months after planting when average temperatures were high ($\geq$20.3^{o}C). Marketable stems ($\geq$50 cm long) in 'Carmen' were produced after a one month's lag period. Of all stems produced by 'Carmen', 56.80%, 31.40% and 11.80% were of yellow (50-59 cm long) blue (60-69 cm long) and white ($\geq$ 70 cm long) grades, respectively. 'Carmen' had the longest vase-life compared to 'Pink Perfection' and 'Marina' cultivars. It is, therefore, suggested that 'Carmen' could be planted most of the time of the year, depending on the availability of irrigation facilities. Its production as a cut flower could be concentrated for the local market due to its poorer stem quality (length). 'Carmen' could also be used as a bedding plant.

The flowering of 'Marina' and 'Pink Perfection

required the May-August cool period for flower induction and initiation. Optimum flowering in 'Marina' and 'Pink Perfection' occurred around August to September. No flowering was observed during the drier warm periods between December and April. The response to temperature suggest that 'Marina' and 'Pink Perfection' be planted during the October-November short rainy season. This would allow sufficient growth of the rhizomes and shoots, ready to receive the cool May-August temperatures in the next year. 'Marina' cultivar could possibly perform better at higher altitudes than those experienced at Limuru. This could improve the number and marketability of the cut flowers.

Many Parigo hybrids of Alstroemeria currently being introduced into the country could provide a wider range of colours, higher yields and better marketability of Alstroemeria cut flowers if found adaptable. Areas with altitudes above 1500 M that provide the necessary cool temperatures required for flowering of Alstroemeria could be exploited for the growing of this crop in Kenya. Such areas include Kinangop, Kiambu, Kisii, Wundanyi, Nyeri, Meru etc.

Pruning of 'Marina' first before the May-August cool period promoted production of new shoots that flowered due to the conducive temperatures. The cut flowers were of better quality (stem length and diameter). The improvement in stem length may not pay much since most of the floral stems from unpruned hills were also of first (white) grade ($\geq$ 70

cm long). The production of more and wider stemmed (a quality attribute) floral stem is very important. For the first 9 weeks after pruning, there was little crowding of stems in pruned unlike unpruned hills. A higher proportion of cut flowers from unpruned hills than pruned ones were leggy and therefore of poorer quality. This problem was observed in pruned hills 9 weeks after pruning. It is suggested that during the drier periods of the year, pruning should not be done. This would allow greater growth of the rhizomes and shoots, through increased photosynthesis. Blind shoots should be removed, however, on the onset of the cool season to minimize competition for nutrients, water and light, as was done in this study. The wide leaf angles and the higher leaf number shown by Alstroemeria especially during the dry season could be used as an index for pruning of unwanted blind shoots. During flowering, continuous shoot thinning should be done by removing the unmarketable leggy shoots.

Prepared silver thiosulphate complex and chrysal improved the vase-life of Alstroemeria cut flowers cvs 'Carmen', 'Marina' and 'Pink Perfection'. Results suggested that possibility of treating cut flowers with these preservatives during peak production periods, when the farmer cannot sell all his produce due to lack of airfreight space. This would greatly reduce the heavy losses often experienced by farmers resulting from short vase-life of cut flowers. Silver nitrate used to prepare silver thiosulphate is very expensive, and the cost-benefit ratio should be assessed before use. Chrysal is cheaper and just as efficient as the prepared silver thiosulphate complex.

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Appendix AI: Climatic data of Limuru area 1984/86

Month/year		July 1984	August 1984	September 1984	October 1984
Week from planting					0
Temperature (^{o}C)	Mean minimum	10.2	9.1	10.0	11.5
	Mean maximum	18.9	19.5	22.7	20.3
	Average	14.4	14.3	16.3	15.6
Rainfall (mm)		15.5	3.5	7.0	159.5

November 1984	December 1984	January 1984	February 1984	March 1984	April 1984
1-5	6-9	10-14	15-17	18-22	23-26
11.5	10.4	10.7	11.5	11.5	11.9
20.6	22.1	25.0	23.9	23.1	21.3
16.0	16.3	16.4	17.7	17.3	16.3
124.3	58.0	5.0	91.0	112.0	241.5

May 1985	June 1985	July 1985	August 1985
23-31	32-35	36-39	40-44
11.5	9.6	8.6	9.0
20.0	19.3	17.1	18.0
15.7	14.5	12.9	13.5
166.0	37.0	27.0	19.0

A2: Days from planting to flowering (Taken when a mean of 5 flowering stems was recorded), of Alstroemeria.

	Block 1	Block 2	Block 3	Totals
'Carmen'	131	126	138	395
'Marina'	238	245	252	735
'Pink Perfection'	217	217	210	644
	586	588	600	Y:1774

Analysis of variance

Source of variation	df	SS	MS	Fcal
Total	8	20856.89	2607.1113	
Block	2	38.22	19.11	0.46 NS
Variety	2	20653.556	10326.778	250.17
Error	4	165.114	41.2785	

NS - Not significant

A3: Average length of flowering stems of Alstroemeria

	Block 1	Block 2	Block 3	Total
'Carmen	49.05	44.59	44.72	141.06
'Marina'	85.80	79.93	83.06	248.79
'Pink Perfection'	85.09	99.90	97.97	282.96
	219.94	224.42	228.45	Y:672.81

Analysis of variance

Source of variation	df	SS	Ms	Fcal
Total	8	3813.6416	476.7052	
Blocks	2	12.08126	6.04063	0.17NS
Varieties	2	3656.5502	1828.2751	50.43
Error	4	145.01014	36.50507	

NS - Not significant

A4: Percent marketable stems of Alstroemeria

Variety	Block			Total
	1	2	3	
'Carmen'	42.00	43.53	41.70	127.23
'Marina'	84.30	82.90	79.94	247.14
'Pink Perfection'	89.52	89.00	89.44	267.96
	215.82	215.43	211.08	Y:642.33

Analysis of variance

Source of variation	df	SS	MS	Fcal
Total	8	3858.3064	428.70071	
Block	2	4.6158	2.3079	1.25NS
Variety	2	3846.3126	1923.1563	1042.64
Error	4	7.378	1.8445	

A5: Shoot morphology: leaf angle (^{o}C) of Alstroemeria

Variety	Shoot	Rep 1	Rep 2	Rep 3	Totals
'Marina'	Blind	555	540	540	1635
	Non-marketable (flowering	500	510	510	1520
	Marketable (flowering)	565	475	440	1380
'Carmen'	Blind	520	460	460	1440
	Non-marketable (flowering)	315	300	300	915
	Marketable (flowering)	255	260	255	770
'Pink Perfection'	Blind	540	565	540	1645
	Non-marketable (flowering)	400	395	400	1195
	Marketable (flowering)	320	280	280	880

Analysis of variance

Source of variation	df	SS	MS	Fcal.
Total	26	308540.74	11866.952	
Variety x shoot	8	303607.41	37950.926	138.47
Variety	2	111346.30	55673.15	203.13
Shoot type	2	163118.52	81559.26	297.58
Inter.	4	29142.48	7285.62	26.58
Error	18	4933.33	3.08333	

A6: Shoot morphology: Number of leaves on 15 cm of flowering stem below the cyme in Alstroemeria.

Variety	Shoot	Rep 1	Rep 2	Rep 3	Totals
'Marina'	Blind	464	415	444	132.3
	Non-marketable (flowering	253	285	285	823
	Marketable (flowering)	112	118	117	347
'Carmen'	Blind	354	373	360	1087
	Non-marketable (flowering)	246	255	237	738
	Marketable (flowering)	89	83	85	257
'Pink Perfection'	Blind	479	449	482	1410
	Non-marketable (flowering)	308	285	276	869
	Marketable (flowering)	117	122	125	364
					Y:7218

Analysis of variance

Source of variation	df	SS	MS	Fcal.
Total	26	479280	18433.846	
Variety x shoot	8	475750	59468.75	303.242
Variety	2	18746	9373	47.790
Shoot	2	451979.56	225989.78	1152.356
Inter.	4	5024.44	1256.11	6.41
Error	18	3530	196.11	

A7: Effect of shoot on the number of new shoots formed in Alstroemeria.

Treatment	Rep 1	Rep 2	Rep 3	Rep 4	Rep 5	Total
Prunned	120	110	105	114	120	569
Control	42	40	35	45	39	201
						Y:770

Analysis of variance

Source of variation	df	SS	MS	Fcal.
Total	9	13766.00	1529.56	
Treatment	1	13542.40	13542.40	484.50
Error	8	223.60	27.95	

A8: Effect of shoot on the average length (cm) of flowering stem (11 flowering stems sampled and measured at random) of Alstroemeria.

Prunned	115, 114, 116, 117, 118, 118, 119, 120, 123, 125, 130	1315
Control	90, 92, 94, 95, 96, 96, 97, 98, 99, 100, 101	1058

Analysis of variance

Source of variation	df	SS	MS	Fcal.
Total	21	3340.5909		
Treatment	1	3002.2272	3002.2272	177.45
Error	20	338.3637	16.9182	

A9: Effect of shoot on the width (diameter) of (cm) in Alstroemeria.

		Totals
	1.09, 1.03, 0.93, 0.94, 1.09, 1.10, 1.19, 1.22, 1.05, 0.96, 1.25	11.87
Control	0.90, 0.84, 0.93, 0.97, 0.96, 0.93, 0.91, 0.89, 0.87, 0.90, 0.92	10.02
		Y:21.85

Analysis of variance

Source of variation	df	SS	MS	Fcal.
Total	21	0.2839		
Treatment	1	0.1489	0.1489	22.06
Error	20	0.1350	0.00675	

A10: Effect of shoot ... on percent graded flowers of Alstroemeria

Grade	Control					Total	Prunned					
	Rep 1	Rep 2	Rep 3	Rep 4	Rep 5		Rep 1	Rep 2	Rep 3	Rep 4	Rep 5	Total
Yellow (50-59cm long)	2.3	2.4	2.5	2.6	2.7	12.50	0.87	0.90	1.00	1.08	1.20	5.05
Blue (60-69cm long)	2.0	2.1	2.2	2.3	2.4	11.0	1.00	1.90	1.20	1.26	1.30	5.95
White (≥70 cm long)	90.00	95.00	96.00	97.00	98.50	476.50	96.00	97.00	98.00	99.00	99.00	489.00
												Y:1000

Analysis of variance

Source of variation	df	SS	MS	Fcal.
Total	29	60017.874	2069.5819	
Grades	2	59945.222	29972.611	11138.861
Error	27	72.652	2.6908	

A11: Effect of floral preservatives on vase-life of Alstroemeria cut-flowers.

Variety	treatment	Rep 1	Rep 2	Rep 3	Total
	Control	60	72	64	196
	Sucrose	68	64	60	192
'Marina'	Silver thiosulphate complex (S.T.S.)	68	84	88	260
	S.T.S.+ sucrose	72	76	76	224
	Chrysal	88	84	92	264
	Chrysal + sucrose	68	76	76	220
	Control	84	84	76	244
	Sucrose	84	84	80	248
'Carmen'	S.T.S.	116	112	116	344
	S.T.S + sucrose	108	104	108	320
	Chrysal	120	120	120	360
	Chrysal + sucrose	104	104	104	312
	Control	72	76	76	224
	Sucrose	76	76	76	228
'Pink	S.T.S.	104	104	104	312
Perfection'	S.T.S. + sucrose	92	92	92	276
	Chrysal	100	100	104	312
	Chrysal + sucrose	92	96	92	280

Analysis of variance

Source of variation	df	SS	MS	Fcal.
Total	53	903.42593	17.0458	
Treatment	5	454.09259	90.8185	9.702
Error	48	449.3333	9.3611	